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Load Flow and Transient simulation of power system using PSSE software. A case study of interconnection for new run of river hydro power plant at Machai with national grid.

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ABSTRACT

The integration of renewable energy systems into electric grid imposes many technical difficulties. To investigate and understand the stability of power system, steady state and transient stability analysis have been proposed with the main focus on power system modeling and dynamic simulation. These studies ensure the secure operation of power system under fault disturbances. Steady state analysis has been performed for calculating power flow on transmission lines, transformers and dynamic analysis for a three phase fault and line to ground fault at critical connection point of units to electric grid respectively. They emphasize on the affect produced by interconnecting new run of river Hydropower plant at Machai with National grid using RETScreen software and Load flow studies and transient stability analysis using PSSE software . The work of power system stability, modeling and simulation has been carried out using PSS®E software which identifies fault clearing time of different power stations in the Network.

Keywords: *Renewable Energy, Dynamic Simulation, Steady States Stability Analysis, Transient Stability Analysis*

1. INTRODUCTION

Large interconnected power systems offer a more complex network regulation system whose role is to transmit electricity from generation side to consumer side.The power system stability is the ability of power system to return to steady state without losing Synchronism (1). The massive integration of renewable energy sources into the grid creates new challenges because of their highly intermittent and variable generation these have been sorted out using RETScreen software(2). Moreover, in order to examine the power system's stability and define the potential integration of distributed generation into the grid, steady state and dynamic simulations need to be conducted (3). Steady-state analysis is based on the calculation of load flow on the voltage profiles of system bus bars, transmission lines and transformers (4).

Load-flow studies deliver an Organized and rigorous close-in to judge distinct voltages of buses, phase angles, real and reactive power through various branches. Load Flow studies have been carried out using Fast Decoupled Technique.The main aim of the simulation program consists of comprehensive transmission system planning and reinforcement including optimal power flow and transient stability analysis.Fixed slope decoupled Newton Raphson method has been employed for load flow studies of 132KV Dargai Network in PSS®E before and after interconnection of 2.679MW Hydro- generator at Machai to the National grid.

Load flow analysis is performed under the category of steady-state analysis while transient stability is performed under dynamic analysis. Power flow solutions provide guidelines for economic dispatch, fault analysis and stability analysis. The analysis of 132KV Network in PSS®E underlines all these computational tasks. Newton- Raphson method is generally employed for power flow solutions of any Network in PSS®E. [4]In performing Power Flow/Load Flow and stability analysis theoretic analysis of the numerical algorithm such as Convergence, efficiency and numerical stability have a direct bearing on the algorithm implementation [4]. Stability studies are carried out so that the system can withstand credible disturbances. [5] It's done for the settlement of functional limitations of 132KV Network.The voltage of the bus & power angles is affected by power flow and vice versa.

Transient stability study helps engineers whether the synchronous machines will remain in Synchronism for a given perturbation (5).

Transient stability is a measure of operating condition and disturbances while steady state stability is a function of operating condition (5).Dynamic stability analysis involves investigation and prediction of the network behavior when faced with sudden disturbances. Especially three phase faults created by tripping of transmission lines, transformers or bus bars connected to generators (6).

Dynamic Simulation of 132 K Network under PESCO is carried out in PSS®E utilizing data of Generators, Transformers, Transmission lines and respective branches before interconnecting new run of river Hydro-generator of capacity 2.679MW and after interconnecting it to Mardan-II bus.

Circuit breaker selection with appropriate rating and relay settings for coordinating fault analysis i.e. simulating the Network in PSS®E transient studies are carried out.

PSSE offers fault analysis feature with IEC-60909 option which needs; fault type, level of simplicity desired for fault current calculation, details of fault location with faulty buses, details of connected generators, transformers & Motors.Similar studies have been carried out on a standard bus test system integrated with a large PV Plant using ETAP Software and the effect of Solar Power Penetration on grid is assessed through steady state analysis with a focus on:
1.Voltage variation in all buses 2. Slack bus power 3. Line Loading effect and system losses

Through Transient Stability Module in ETAP software the impact on transient stability performance of the grid is studied for the following transient events:
1. Effect due to a bus fault 2. Effect on critical clearing time 3. Effect due to load rejection. (16)

Dynamic voltage stability simulations using the ETAP software demonstrate that connecting the PV to Houn substation increases the voltage profile at the particular bus bar.Thus, integrating of a PV system into a distribution network improves the system voltage stability.(17)

The ETAP software simulation for a medium-voltage IEEE 30-bus system to evaluate the impact of the penetration of LS-PV and steady-state analysis of the system and transient analysis of switching the PV farm into and out of the grid have been carried out.The simulation results showed that the voltage stability impact of the LS solar PV system varies depending on the bus status, disturbance location and disturbance duration.In addition, network terminal voltage, generator terminal current, and output electrical power were thoroughly analyzed.(18)

2. DESCRIPTION OF 132KV ELECTRICAL NETWORK UNDER PESCO

The Network studied for stability after interconnecting new run of river hydropower plant at Mardan II bus is 132KV Transmission Network with 220KV transmission line to which swing generator at Chakdara has been connected putting a limit to the extendable Network up to 500KV in this domain**.** This 220KV Chakdara bus has been chosen as reference for the rest of simulations in PSS®E.Short circuit analysis has been carried out as per IEC-60909 standard and its results are used for selecting protective devices and their coordination (1, 7-9).The objective of this work is to analyze NTDC transmission network with interconnecting 2.679MW of renewable energy in the form of Hydropower plant through performing steady state analysis and dynamic simulation.

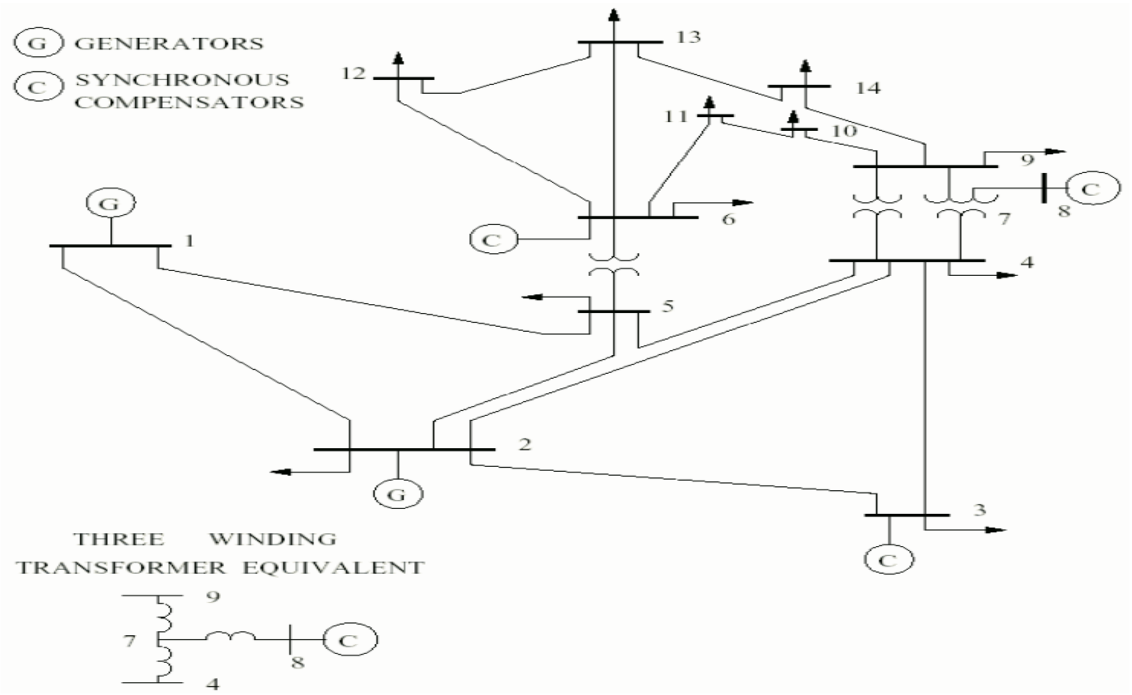

Fig. 1: IEEE 14 Bus System

In a transmission network e.g., 132 KV Network modeled is PSS®E Chakdara 220KV shown as bus 701 in Fig 2 has been chosen as reference for all simulations. If one bus of a Distribution Network under investigation is connected to a higher voltage level it's taken as slack/reference bus or θVbus.

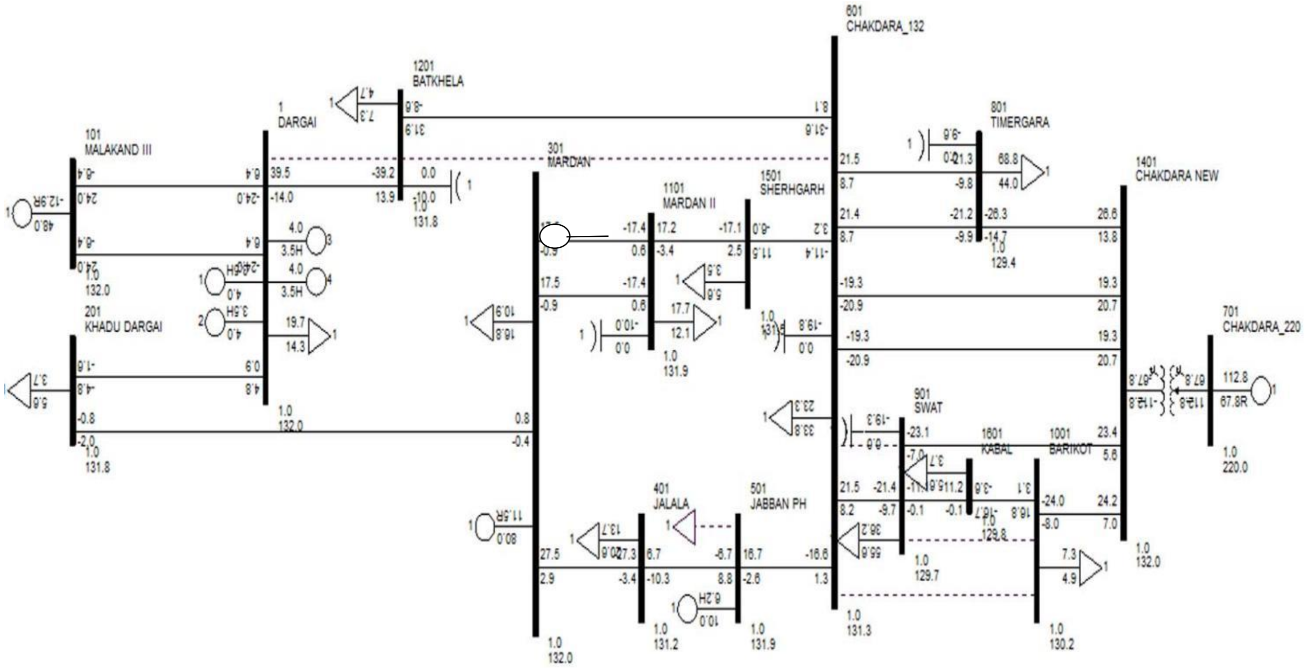

Fig. 2: Single Line Diagram of 132KV Network under PESCO

3. LOAD FLOW STUDY AND TRANSIENT STUDY ON 132KV ELECTRICAL NETWORK UNDER PESCO (WITHOUT HYDRO AND WITH HYDRO)

3.1 Load Flow Studies

Fixed Slope Decoupled Newton Raphson Technique for Load flow studies with Flat start and switched shunt enabled are employed in PSS®E (3).Load-flow studies deliver an Organized and rigorous close-in to judge distinct voltages of buses, phase angles, real and reactive power through various branches.The principal information obtained from a power flow study before and after interconnecting Hydro generator of 2.679MW to Mardan II bus no 1101 of 132 KV Network is the magnitude and phase angle of voltage at each bus as shown in Fig 3 and Fig 4 and the real and reactive power flows in equipment such as transmission lines and transformers in a power system under balanced three-phase steady state conditions. The power flow is a basic tool for some static power system analysis such as power system security; optimum power flow, state estimation and continuation of power flow (10).Newton-Raphson method(11)and Fast Decoupled Load Flow (FDLF) methods are widely used for Load Flow Studies due to their good convergence and high number of iterations,fast calculation speed compared to Newton method and modest computer storage request.

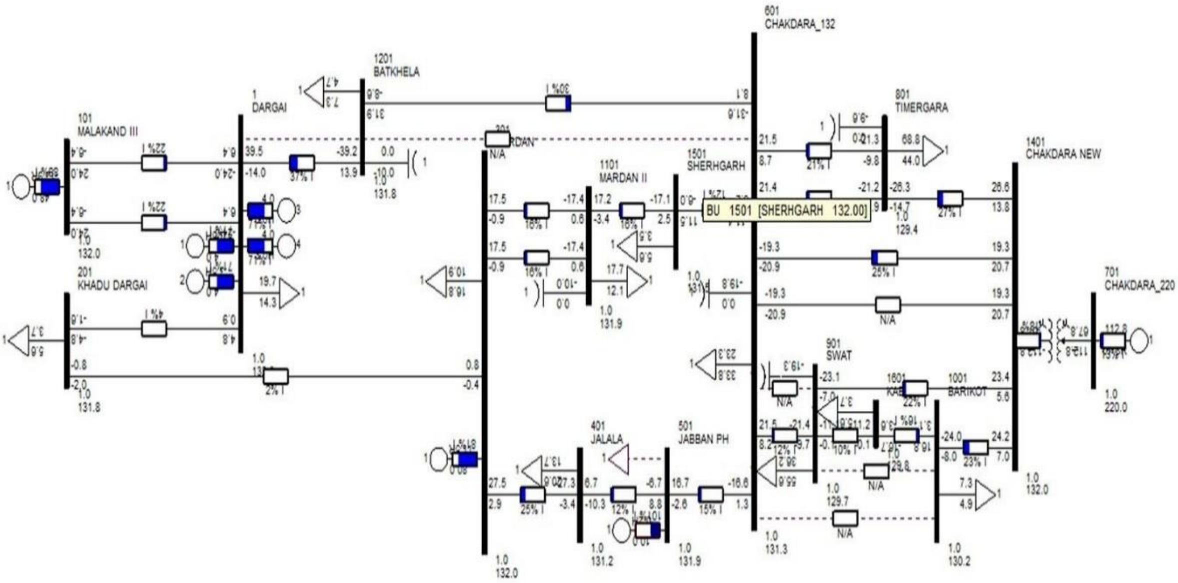

Fig. 3: Over Loading Check on 132 KV Network Before interconnecting Hydro generator at Mardan II bus 1101

The analysis of 132KV Network in PSS®E underlines all computational tasks for economic dispatch, fault analysis and stability analysis. In performing Load Flow and stability analysis theoretic analysis of the numerical algorithm such as Convergence, efficiency and numerical stability have a direct effect on the algorithm implementation(12). Stability studies have been carried out so that the system can withstand under contingencies (13) and to determine the operating limits of system.

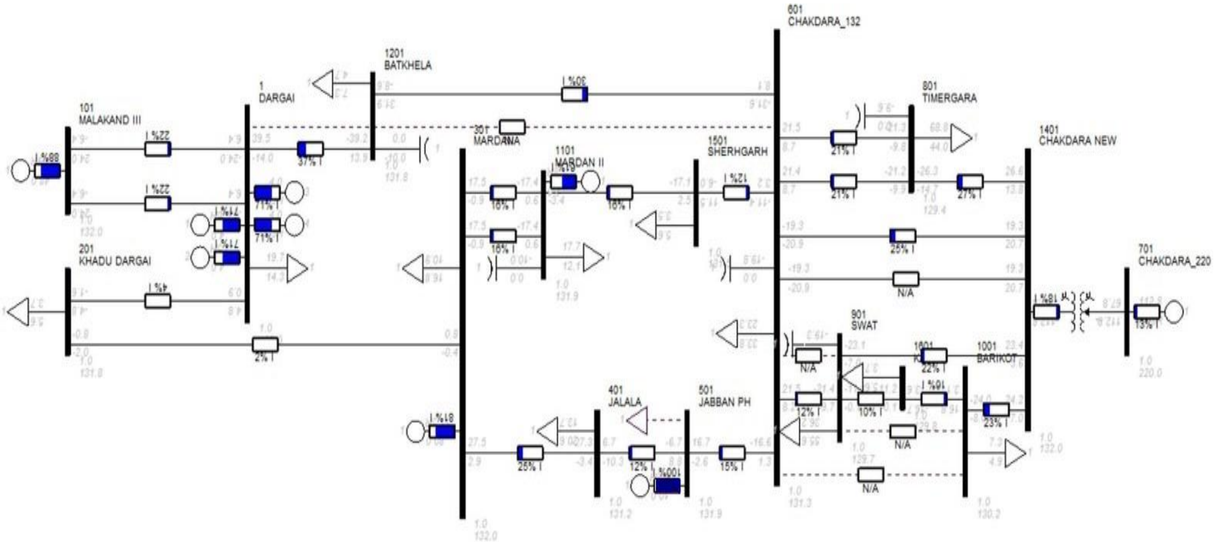

Fig. 4: Over Loading Check on 132 KV Network after interconnecting Hydro generator at Mardan II bus 1101

To this end overload check for successive line outages has been carried out in PSS®E.Energy import and export occur according to grid demand(13). Carefully looking at the diagram in Fig 4 it can be clearly seen that there is no overloading of any bus in the Network not even the Mardan II bus shown as 1101 to which we have connected generator. Jabbah PH shown as bus 501 and JALALA PH shown as bus 401 points to the area where almost all load is concentrated completely satisfies loading conditions.

3.2 Dynamic Stability Analysis of 132KV Network in PSS®E:

For Circuit breaker selection with appropriate rating and relay settings for coordinating fault analysis; the Network is simulated in PSS®E and transient stability studies are carried out without interconnecting Hydro-generator and with interconnecting Hydro-generator.

Dynamic Simulation of 132 KV Network under PESCO is carried out in PSS®E (14)utilizing data of Generators, Transformers, Transmission lines and respective branches.

Dynamic simulation is employed to elaborate specific voltage collapse conditions, collaboration of security (15)and control; including generating units and Transmission Network protection. The performed dynamic analysis examines the immediate response after three phase and Line to ground fault condition and inspects the critical fault clearing time (CFCT). The CFCT is defined as the maximum time during which a disturbance can occur without losing system stability. The calculation of such time ensures the correct operation of the network during various shocks to which it is subjected, in addition it serves as a reference when setting grid protections(16).

Measurement of Critical Fault Clearing Time(CFCT): Critical Fault Clearing Time is obtained by applying 3phase fault on bus bar,starting with 200mSec duration and if Generator survives then we make it 300mSec,If generator trips in 300mSec duration,then we take average f 200mSec and 300mSec i.e. 250mSec and if generator survives at 300mSec duration then we go for 400mSec So by doing iterative method we finally conclude it to some duration.

In order to test the interconnection of Hydro Generator into transmission Network riding through capability over perturbations a three phase fault and Line to Ground fault were applied one second after the initiation of the simulation,the fault duration was increased gradually using the step time of 100 ms until the power system appears to be unstable by observing the output graphs similarly the Network was checked for delayed fault clearing time(DFCT)at 160ms(8-Cycles standard) i.e.Stuck breaker condition as per NEPRA Standard and the total simulation time was defined at 20s.Figure 5 shows the terminal voltage response for Mardan II bus after interconnecting a Hydro generator of capacity 2.679MW and variations in frequency at the faulted buses.

During fault, the terminal voltage at the faulted buses drops to zero. After the fault is cleared this voltage gradually recover to 1pu (fig.5).

Figure 6 illustrates the active power response of all buses during the short circuit occurrence, respectively. The Hydro turbines generators most critical fault occurs on the connection point of the transmission network. Simulation results reveal that a CFCT of 200 ms should not be exceeded to keep the network stability.

During the fault, the active power output decreases to zero for some buses and to low values for other buses. After fault clearing, generators' output power oscillates, for about 5s, and then recovers to its steady state pre-fault value (fig.6).

Figure 7 illustrates Angle plot of all Machines including the newly interconnected generator at Mardan II bus bar in the Network and the rotor of all machines shows major oscillations in the sub transient region after clearing fault for about 5s and then returns to same steady state value before the occurrence of fault at 20s (Fig.7).

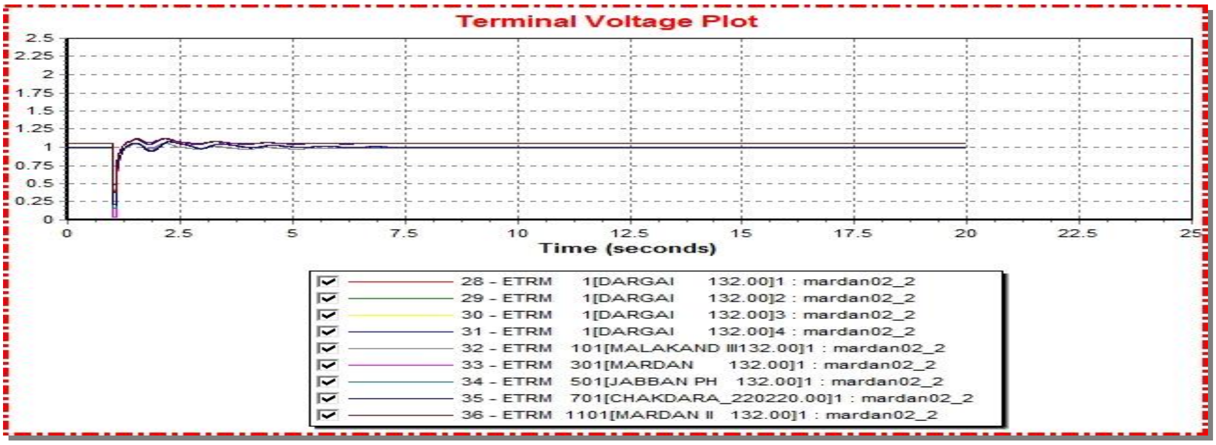

Fig. 5: Terminal voltage response at the all bus bars. .Following a fault which is applied at t = 1.1s and cleared at t =1.16s (8-Cycles standard)

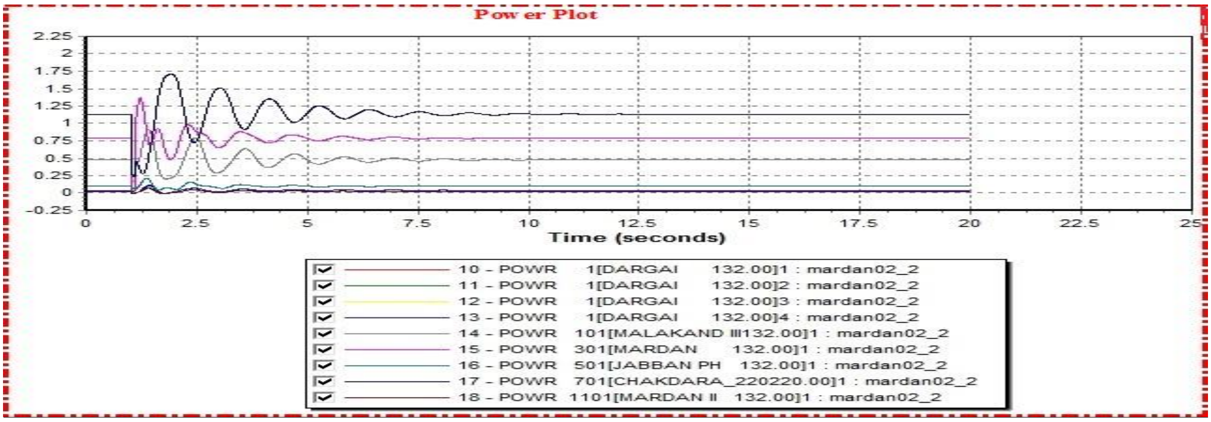

Fig. 6: Power outputs of the all wind farms in operation during the fault incident

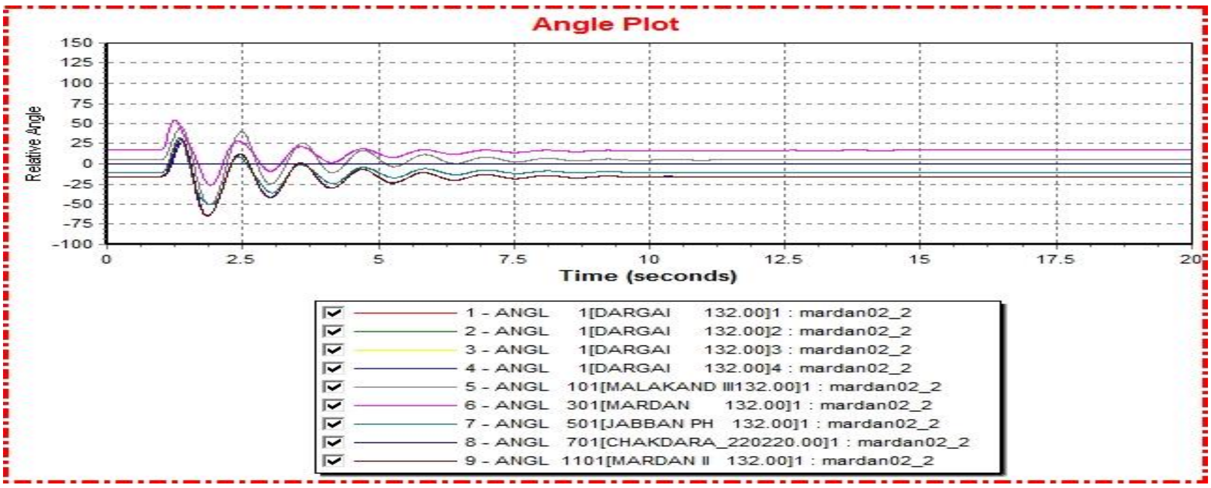

Fig. 7: Oscillations in the rotor angle of generator at all buses in the Network.

4. CONCLUSION

In this research work, load flow studies and transient stability studies of 132 KV network under PESCO of Dargai areas has been conducted after interconnecting new run of river HPP at Mardan II bus. Fast decoupled Load Flow Technique has been applied for Power flow and IEC-60909 technique has been applied for short circuit analysis in PSS®E. The disturbances that cause severe impact on the system are usually of rapid transient nature and Dynamic Simulation serves as quick algorithm to detect these faults. Transient stability analysis has been carried out as per NEPRA Standards. This study has revealed that the network was stable after applying fault at 100m sec (5-Cycle) and stuck breaker condition at 160msec (8-Cycle). The CFCT of the Network was 200msec.the capacity of the Network for further Power interconnection was more than 40%.Future work needs to incorporate with the techniques wind and HVDC interconnection. The work presented in this report can serve as the basis and step towards more practical approach of detecting symmetrical and unsymmetrical faults in an efficient way in a dedicated environment of computation.

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