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Research thesis- Load Flow Studies and Dynamic Simulation of Power System: A case study of interconnection for new Run-of-River Hydropower Plant at Machai with National Grid

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Load Flow Studies and dynamic Simulation of Power System: A case Study of Interconnection for New Run-of-River Hydropower Plant at Machai with National Grid



M.ENGG (Electrical -Power)

Dissertation

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Dedication

Dedicated to my beloved mother, brothers, sisters and beloved late father.

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Abstract

Pakistan's economy is directly affected by Power conjuncture causing energy failure on regular basis for long duration and shut down of industrial units causing social disorganization. Because of population growth and need in economy advancement it's estimated that national electricity demand will continue to grow at 10 % per annum.

Out Of all renewable energies Hydropower is environmental friendly and less expensive. The Utilization of pollution free, highly efficient renewable energy technologies (RETs) has augmented with the passage of time. Power production in RET Screen software and its interconnection to 132KV NTDC Network via Network Simulation in PSS®E has been studied in this report. Two Techniques; Fast Decoupled Load Flow and IEC-60909 have been adopted for Load Flow Studies and Short Circuit Analysis respectively. It addresses the problem of not only electricity shortage but also provide a guide line for future research objectives.

1.1 Objective

The working idea behind this dissertation is to analyze 132KV NTDC Network for steady state stability and transient stability and fault analysis of all buses in the Network before and after connecting generator to it.

1.2 Working Methodology

Standardized PSS®E 50 bus system has been utilized for analyzing the Network .The results obtained from the analysis of the Network for different bus System have been manifested in this thesis .The report has been abstracted as:

- ✓ Steady state stability analysis of the Network using Fast Decoupled Load Flow Technique.
- ✓ Short circuit Analysis of the Network using IEC-60909 fault analysis Technique.
- ✓ Dynamic simulation of the Network as per NEPRA standards.

1.3 Delineation of Dissertation

This report has been separated into four Chapters as described below:

Chapter #1: Preface of Run-Of-River Hydropower Plant Designed in RET Screen

In this chapter the issue of electricity shortage and Procedure of the work carried out in RET Screen has been discussed.

Chapter #2: Background

In this chapter the basic thought, review of literature for the tools used for working out the Network have been summarized.

Chapter # 3: Load Flow Studies

Load Flow Studies before the interconnection of generator to the Network and after interconnection to Mardan II has been discussed in this chapter.

Chapter #4: Dynamic Simulation of 132 KV Network

This chapter discusses the results obtained after running the simulation as per NEPRA standards.

Chapter # 1: Introduction to Run-Of-River Hydropower Plant Designed in RET Screen

1.1 RET Screen Small Hydropower project Energy Model:

Hydropower is full-fledged and oldest renewable energy providing higher than 19% of world's electricity demand.

Small Hydropower Plant ranges in capacity from 1MW to 50 MW. Projects from 100KW to 1MW are categorized as mini HPP and Projects with less than 100KW are categorized as micro Hydropower Plant. The size of Project cannot be defined by installed capacity. Water Head is inversely proportional to the turbine size because water volume utilized by Low Head Plants is higher and large turbine sized is required as compared to High Head Plants.

In Run-Of-River Hydropower plants as shown in Fig 1.1 the flow of stream directly affects power production. The mode of operation for Run-Of-River HPP is the utilization of water available with the natural river flow. There is no water stored for Run-of -River HPP.

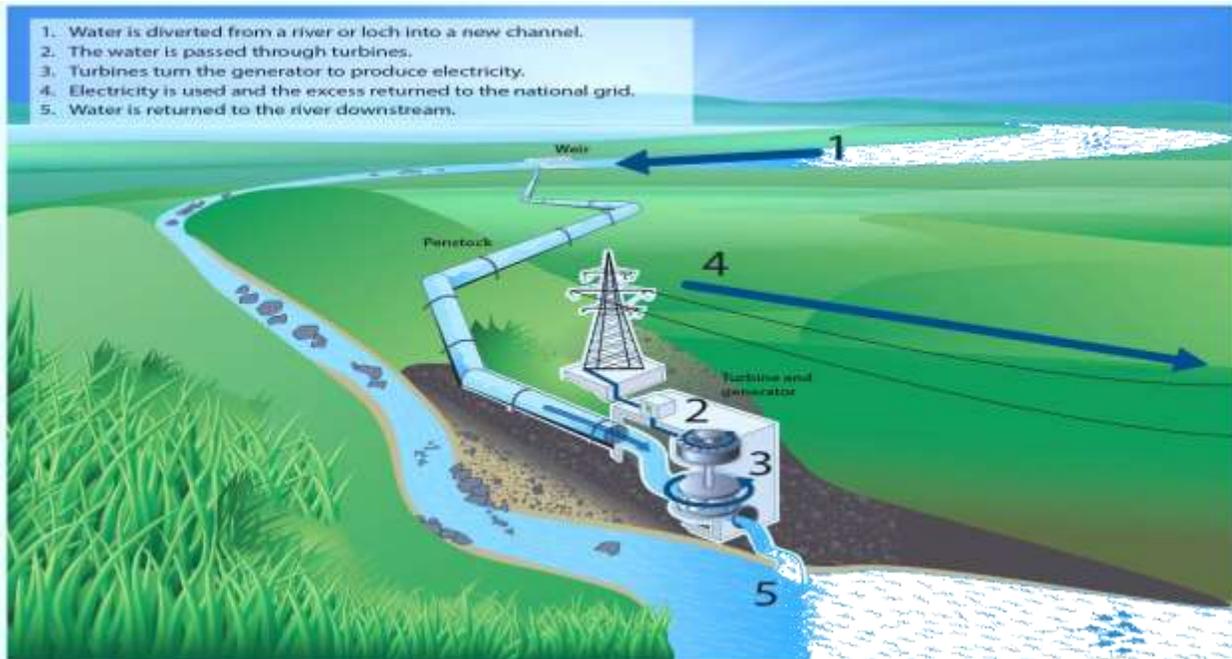


Fig 1.1: Run-of-River Hydropower Scheme

1.2 Mechanical Equipment: Francis turbine and adjustable and fixed pitch Kaplan Propeller turbines are utilized at lower and moderate head. Small hydro turbines can attain efficiencies of about 90%. Most of run of river power projects site where flow changes to a great extent, turbines operating efficiently at extensive discharge like Kaplan Turbine will be used in our RET Screen project for Machai HPP. Machai Hydropower project is located near Katlang in District Mardan of Khyber Pakhtunkhwa (KPK) Province with installed capacity 2.6 MW. [1]

1.3 Electrical Equipment: SHP utilizes two kinds of generators one is synchronous and another is induction. [1]

The RET Screen Software is utilized to calculate industrial, commercial, institutional, Community, residential and utility electricity consumption. Renewable Technologies addressed by RET Screen International are wind, photovoltaic, small hydro and biomass combustion power. The electricity produced from Hydropower plant is equal to the flow per unit of time and water head.

$$\begin{aligned} \text{Electricity Produced} &= \text{Flow} * \text{Water Head} \\ E &= QH \end{aligned}$$

1.4 RET Screen Energy Model:

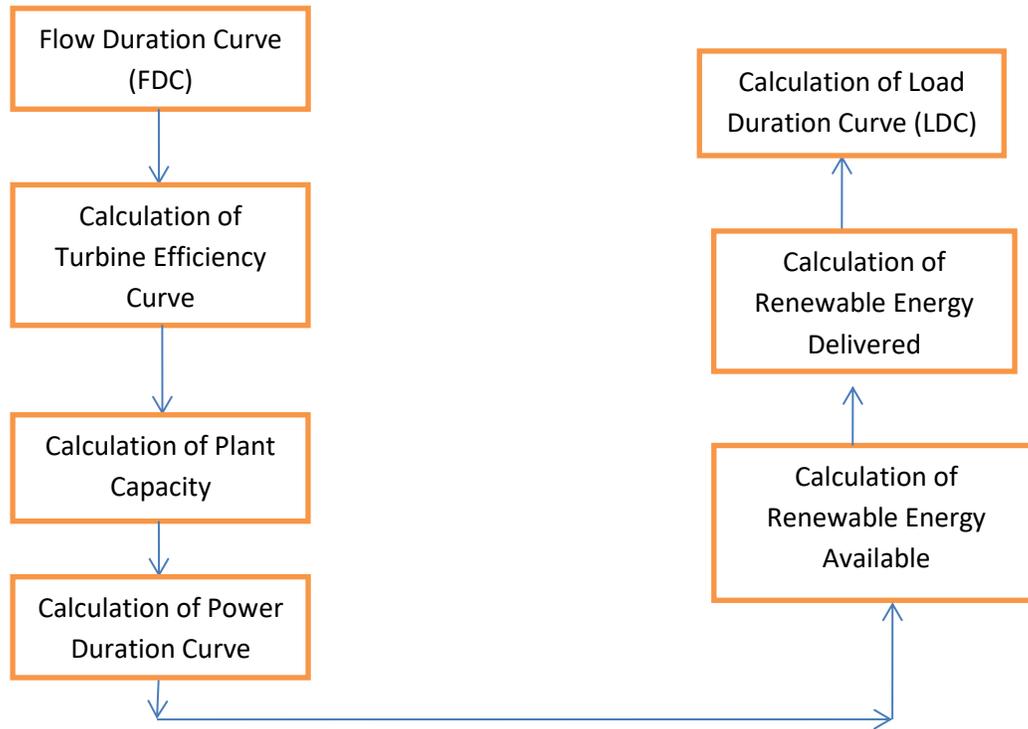


Fig1.2: RET screen Small Hydropower Energy Model Flowchart

1.5 Hydrology: As per RET Screen energy Model shown in Fig 1.2 the Flow duration curve is drawn in RET Screen on the basis of discharge in the river for an average year.

The data from online weather database in RET Screen and FDC are utilized either in manual calculation or by specific run-off method for run-of-river HPP. For Machai project which is a run of river project the Hydrology method is “Specific Run Off” used in conjunction with the RET Screen Hydrology database .Located at Latitude: 34°37'38.27"N and 71°59'23.78"E.

1.6 Flow Duration Curve: The available flow of water over time and as a result the power and energy at a site is assessed by Flow duration Curve. Firm flow is calculated by the FDC Model for electricity production based on other factors as residual flow and the rate percent of firm flow.

In Modeling Machai HPP in RET Screen the Hydrology data of Machai Canal was utilized in MS-Excel to draw the Flow duration Curve as shown in Fig 1.3 Hydrology Data of 313 values in Cumec (m³/sec) of Machai Canal Located in District Mardan was arranged in Descending order in MS-Excel and then the individual values were assigned Rank by using the Function Rank in Excel, Percent Exceedance was also calculated based on Rank Function.

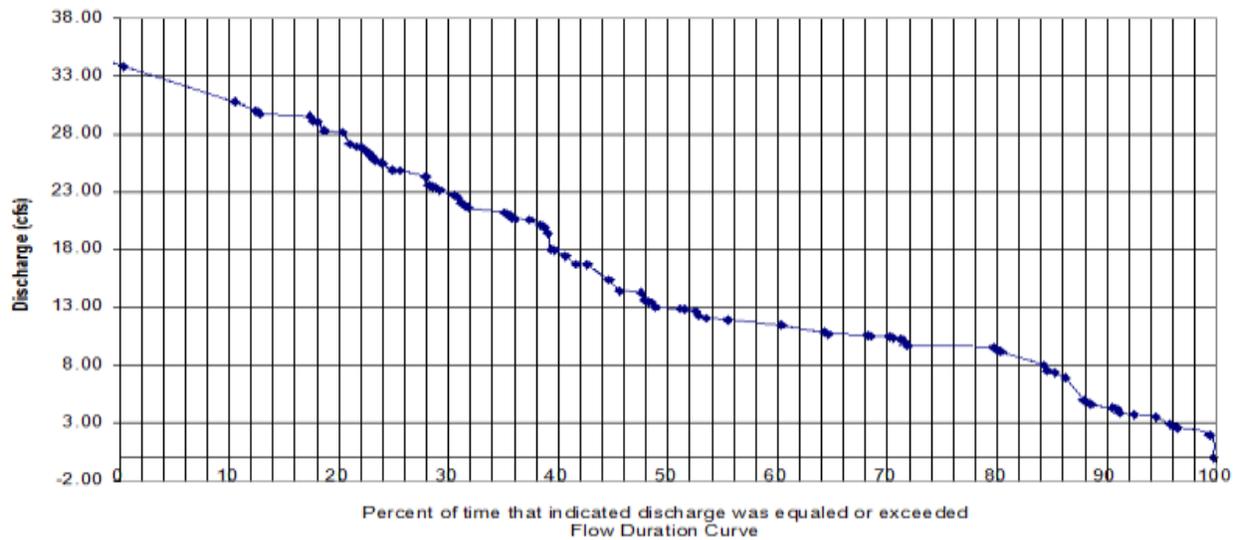


Fig 1.3: FDC For Percent Of Time Discharge was exceeded

As the Hydrology method used for Machai HPP in RET screen is “Specific-Run-Off” the FDC is represented in Normalized form i.e. w.r.t the mean flow. This is given as:

$$Q = RA_d$$

Where R represents specific run-off and A_d represents area available for drainage.

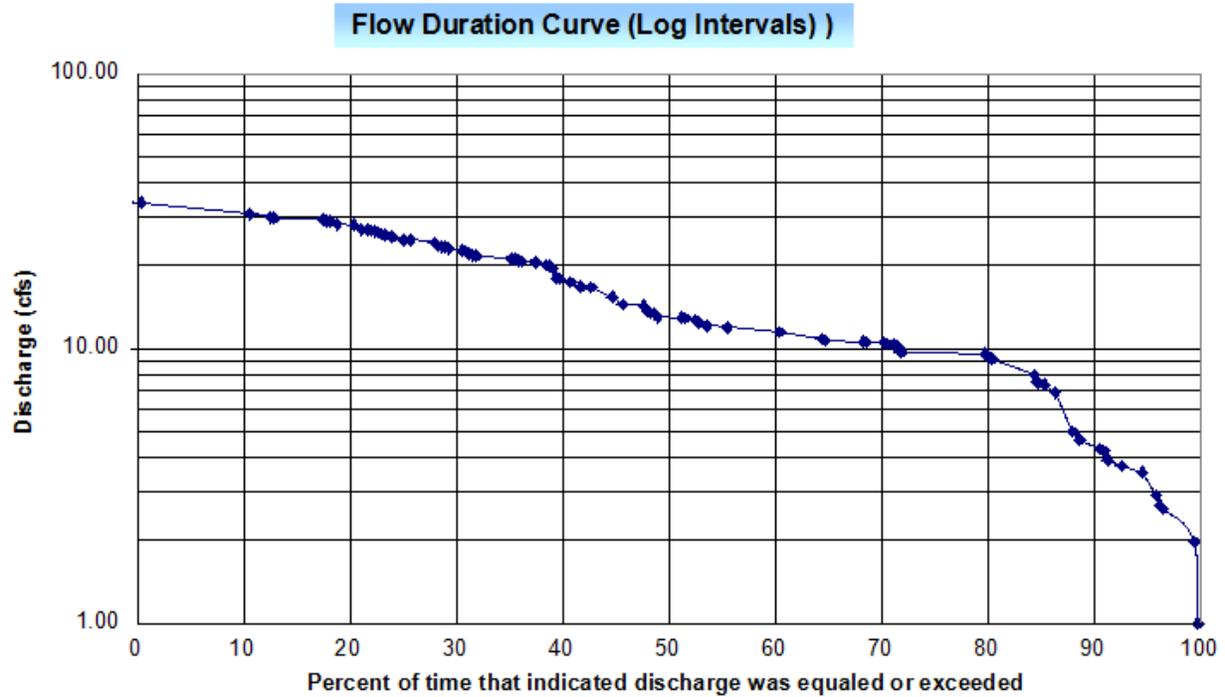


Fig 1.4:Percent Exceedence Log Intervals FDC Of the Discharge for Machai Canal

Flow Duration Curve was drawn in Excel based on Logarithmic Scale as shown in Fig 1.4. We have selected the Logarithmic scale for the FDC in Fig 1.4

Each of the two FDC Drawn in Fig 1.3 and Fig 1.4 are same.

Normalized values calculated in MS-Excel were put in built in Table form in RET Screen ,each value put in Table gave the corresponding values of Flow in Cumec for Machai Canal taken from Sub-Division Irrigation Dargai Malakand.

Each value of Machai Canal Flow put in RET Screen gave Kaplan Turbine Efficiency.

1.7 Kaplan Turbine Efficiency:

Kaplan Turbine Known as Propeller Turbine along with adjustable blades designed specifically for low heads. These propeller blades works reverse. The shaft Power displaces water axially creating thrust which causes forces on Kaplan turbine moving it axially. Kaplan turbine designed specifically for low heads ranging from 10m to 70m and Power output from 5 to 200MW.

RET Screen Energy Model for Hydro Turbine Type Kaplan for Design flow Value of 40cumecs and head Value 8.1m and the corresponding flow values for the given Normalized flow values in table gave Kaplan turbine Peak Efficiency 96% and Efficiency at design Flow as 95.5% shown in Fig 1.5

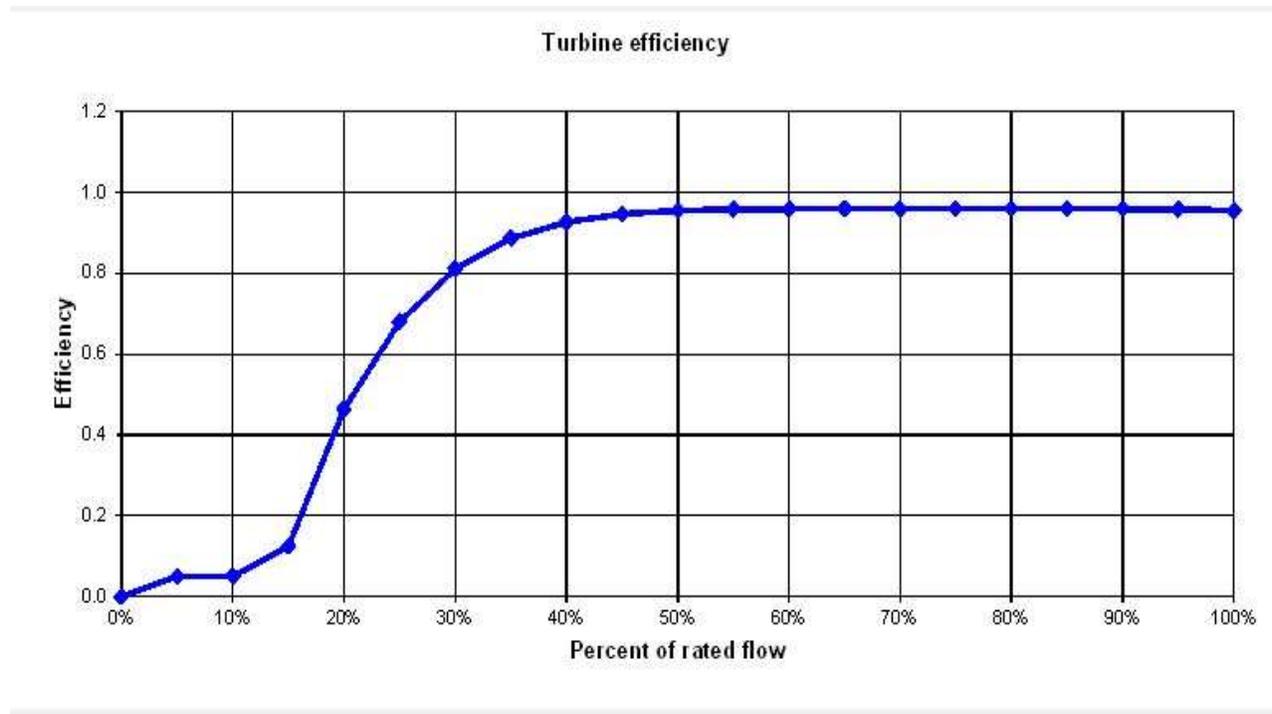


Fig 1.5: Kaplan Turbine Head: 7m, Discharge: 40m³/sec

The flow at peak efficiency was 30 Cumec for the power output of 2.679MW.the maximum hydraulic losses were 5% and miscellaneous losses 2%.the available flow adjustment factor was 1.0.and Availability was 94%.

Kaplan Peak Efficiency is calculated with this formula:

$$Q_p = 0.75Q_d$$

1.8 Availability of Power as a Function of Flow:

Power Obtained from Small Hydropower Plant at a given discharge Q is calculated from the given equation:

$$P = \rho Q g [H_g - (H_{hydr} + H_{tail})] (1 - l_{trans})(1 - l_{para}) \dots \dots \dots 1$$

Where ρ is the density of water (1000kg/m^3) g is the gravitational constant (9.81 m/s^2), H_g is gross Head and H_{hydr}, H_{tail} are Hydraulic losses and tailrace effect and related to discharge Q and e^t is turbine efficiency at design flow since e_g the generator efficiency l_{trans} transformer losses, l_{para} Paralistic losses are assumed independent from flow considered.

Hydraulic losses are calculated with this formula:

$$H_{hydr} = H_{hydr} = H_g l_{Hydr} = Q^2 / Q_{des}^2$$

Where $l_{hydr,max}$ is the maximum hydraulic losses specified by the user, and Q_{des} the design flow.

$$H_{tail} = H_{tailmax} (Q - Q_{des})^2 / (Q_{max} - Q_{des})^2 \dots \dots \dots 2$$

Where $l_{hydr,max}$ is the maximum hydraulic losses specified by the user, and Q_{des} the design flow.

$$H_{tail} = H_{tailmax} \dots \dots \dots 3$$

$H_{tailmax}$ shows maximum tail water effect .Gross head reduced to a certain level depending upon the river flow.it will be maximum during times of greater discharge in the river. Q_{max} is highest discharge in the River and equation (2) is applicable to river discharge higher than the plant designed discharge. E.g. when $Q > Q_{des}$.

1.9 Plant Capacity:

Calculation of Capacity of Plant is done with the help of the following equation:

$$P_{des} = \rho Q_{des} g [H_g - (H_{hydr} + H_{tail})] (1 - I_{trans})(1 - I_{para}) \dots\dots\dots 4$$

P_{des} shows capacity of plant at design flow and et_{des} is efficiency of turbine at a given flow.

In RET Screen the plant capacity obtained from Hydrology data is 2.679M W.

1.10 Power Duration Curve: The flow values in Cumec 313 values from Sub division irrigation Dargai Malakand are utilized in the following equation to evaluate power:

$$P = \rho Q g [H_g - (H_{hydr} + H_{tail})] (1 - I_{trans})(1 - I_{para}) \dots\dots\dots 5$$

These 313 discharge values are utilized for calculating FDC and the corresponding values of power obtained from the above equation are used to calculate the Power duration curve as shown in Fig 1.6

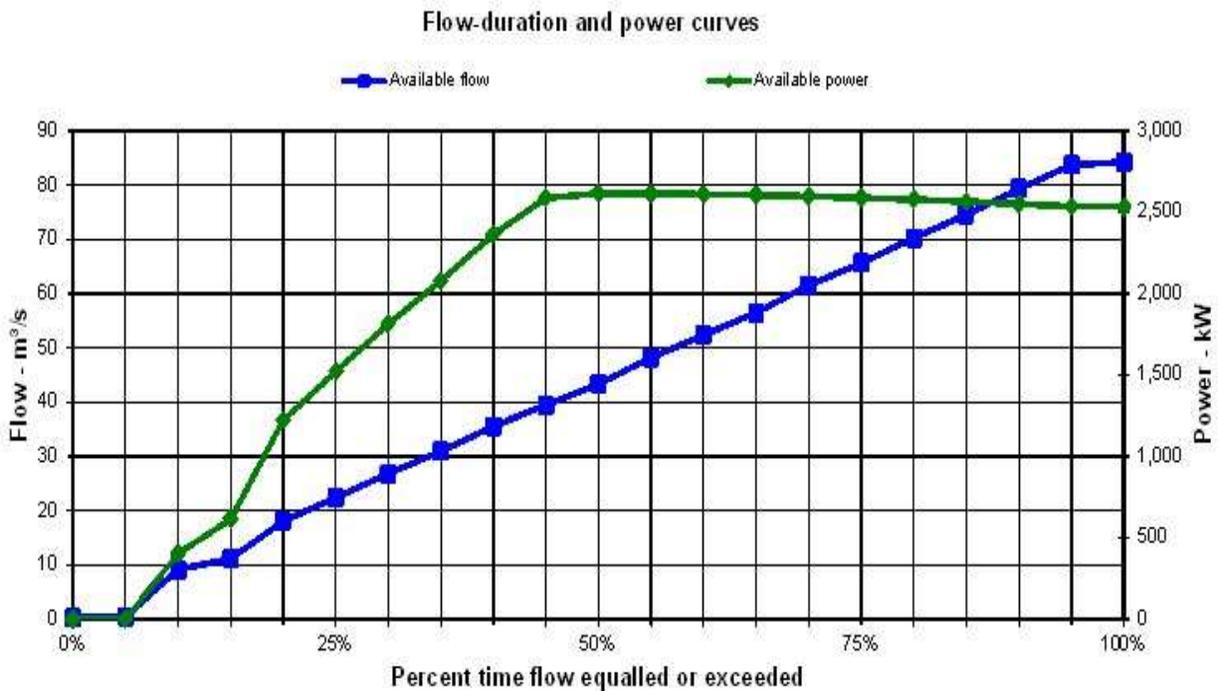


Fig 1.6: Power and Flow duration Curve

For the calculation of Capacity of Plant, firm Capacity and Renewable energy the specific value of residual flow Q_r is deducted from every value of FDC.

Available maximum discharge/flow utilized by turbine is called design discharge. It's defined as:

$$Q'n = \max(Q_n - Q_r, 0) \dots \dots \dots 6$$

1.11 Renewable Energy acquirable:

Attainable renewable energy is calculated by the region underneath power duration curve. Energy

E_{avail} (kWh/year) obtained from P (in kW) by:

$$E_{avail} = \sum_{k=1}^{20} \left(\frac{P_{5(k-1)} + P_{5k}}{2} \right) \frac{5}{100} 8760 (1 - l_{dt})$$

Where l_{dt} defines the loss factor per annum during shutdown .The above equation defines the amount of renewable energy available.

$$E_{avail} = E_{dvd}$$

For Central grid applications the electrical energy/power available will be integrated to the Dargai grid/132Kv Network. The capacity of the grid is 200Mw.

1.12 SHP Capacity Factor:

The per annum capacity factor is proportional to discharge Q and efficiency of use. It's denoted with the sign K . All small hydropower Plants are designed on the basis of a capacity factor of 70% to 80%.

$$\text{Capacity Factor of Plant, } K = \frac{\text{Precise value of energy available}}{\text{Maximum energy available}} \dots \dots \dots 6$$

$$= \frac{\text{Mean Demand x Time}}{\text{Plant Capacity x Time}}$$

The RET screen energy Model of Machai HPP based on the Hydrology data gave a value of capacity factor of 57% for a plant capacity of 2.679MW which is much closer to the practical limit.

1.13 Financial Analysis of Small Hydropower Plant:

Financial analysis is mainly performed using the RET Screen software supported by extensive bibliographic review of relevant technology and financial information. Financial analysis of Small Hydropower Plant with a capacity of 2.679MW located at Mardan District for a period of 30 years is indicated by Cumulative cash flow graph. As indicated by the graph in fig 1.7 there's no cash flow in the first year.

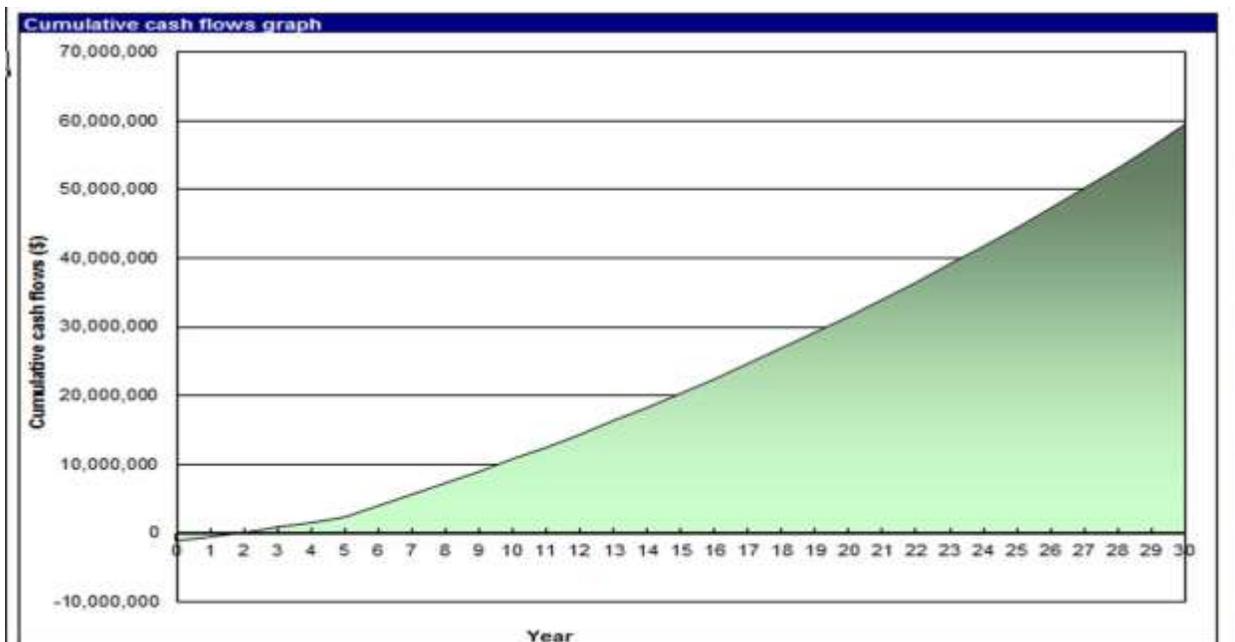


Fig 1.7: Cumulative cash flows graph of 2.679MW SHP in 30 Years Life Span

The cumulative cash flow graph of Small Hydropower Plant after 30 years is approximately US\$60,000,000. The cumulative cash flow being the aggregate of the annual cash flow statements of the plant from year 1 to year 30. The electricity export rate which was set at 100.00\$/MWh directly affects the cash flow graph. However an increase in the electricity cost would mean that consumers would have to pay more in terms of the electricity tariff. For an electricity tariff of

100US\$/MWh the cash flow is negative i.e.US\$10,000,000. This indicates that the power plant is making a loss as the annual costs are more than the annual income.

Required technical input data are obtained through direct field measurements and from existing environmental and technical information databases online. Google Earth was also used for the topographical study of the target site and to determine the gross head of the river with respect to the position of the hydropower turbine. [13]

Chapter#2: Background

2.1 Introduction: Standard tools for the analysis of 132KV Network for transmission expansion, planning and dynamic simulation was taken on utilizing Techniques in PSS®E Software of Siemens PTI.

Load Flow Studies is carried out for making it sure that whether the system is operating normally or not. The Load Flow studies for 132KV Network is done before connecting 2.69MW generator at Machai to Mardan II and after connecting to Mardan II [5]

In order to analyze the Network designed in PSS®E for short circuit categorizing it as three-phase and single phase fault currents IEC-60909 Technique is used.

As per NEPRA Standards constant three phase faults if occur on transmission line and related entities 5-cycles will be taken by circuit breaker to clear it. [10]

2.2 Load Flow Studies:

In Electrical Power system the flow of real and reactive power is called Load Flow. In generating stations generators produce electrical power which is transmitted through transmission lines in the Network to load centers. In order to plan and determine the steady state operation power system engineers use Load flow analysis.

A power system when put to small disturbances and if it remains synchronized such a System is called steady state stable. Due to persistent changes in load; Power Systems are mostly categorized as steady state stable. [1] A Power System is never in steady state, variations in load and minor perturbations in the form of transmission line tripping, faults, generator loop loss and large load changes occur.

Power Flow Studies deliver a Systematized and accurate belly up for determining different bus voltages, angles of phase, real Power and Var flows amid distinct branches. Various *operational*

parameters underneath different circumstances, such as real, reactive power losses, can be derived from Load Flow analysis. These attributes are important in investigation, design and comparison of different options for interconnection between grid and hydro power plants. Additionally the network configuration and setup for the load-flow analysis has been used to form the basis for the subsequent work related to the power system [2].

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] Stability analysis is 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. For Load flow studies of 132KV NTDC Network of Dargai/Malakand area the Network is designed using a Graphical user interface software PSS®E.

Fixed slope decoupled Newton Raphson method has been employed for load flow studies of 132KV Dargai Network in PSS®E after interconnection of 2.679MW generator at Machai to the National grid.

The best overall approach for computing power flow solutions up to and beyond the critical point is by using supplementary technique.

$$F(\Theta, V) = \lambda K \dots \dots \dots (1)$$

In equation (1) a conventional Newton Raphson Fixed slope decoupled method is used to compute power flow solutions for successfully increasing Load levels until solutions cannot be reached.

In PSS®E Fixed slope Decoupled Newton Raphson Technique for Load flow studies with Flat start and switched shunt enabled are employed .[1]

This method is adopted due to lesser number of iterations and faster rate of convergence.

A bus in a transmission Network to whom a larger unit is connected is called reference bus. When a bus is connected to a higher voltage level in a distribution Network it's called Slack bus. Reference bus is also called θV bus because value of voltage is known but reactive power is unknown. [5]

In power flow calculations for 132KV Network, Chakdara 220KV has been taken as reference bus.

An angle of voltages, currents of other buses is derived pertinent to the reference.

Real Power generated always equal to the Power utilized at consumer side combined with losses .The aim of the Load Flow study is to evaluate the voltage which has a direct impact on the losses in various branches of the Network depending upon the current. The real power is inserted with changing values to remunerate for variations in losses while the angle of slack bus is kept constant.

Power for slack bus = Total Power going into the system - Total Power going out of the system
Transmission +line loss

2.3 Stability of Power System:

Maintaining Synchronization or equilibrium is called stability. When System is exposed to any perturbation whether small or large and the effect of those disturbances on power system is observed; stability of Power System play a key role at that instant. [1]

There are two types of stability based upon the nature and types of perturbations:

- 1. Steady State Stability
- 2. Dynamic State Stability

2.3.1 Steady State Stability:

A power system when put to small disturbances and if it remains synchronized such a System is called steady state stable. Due to persistent changes in load; Power Systems are mostly categorized as steady state stable. Power System not meeting such conditions is less advantageous. [1]

2.3.2 Dynamic state stability:

The Dynamic stability of a Power System is defined as the ability to maintain synchronization after heavy perturbations. These perturbations do not occur very often but their occurrence affects the power system severely. The stability of Power System is a must under such conditions. [1]Contingencies are also defined as transient conditions. The Occurrence of Disturbance in a Power System causes contingency condition; if it has steady state stability but do not have transient stability. Both steady state and transient stability lead to good operation of Power System.

2.4 Dynamic Analysis of 132KV Network in PSS®E:

Dynamic simulation is employed to elaborate specific voltage collapse conditions, collaboration of security and control; including generating unit and Transmission Network protection and control e.g. Generator excitation Protection, Armature Over current protection, Over current protection of transmission line, control of Capacitor bank, phase shifting regulators and under voltage load shedding. Dynamic simulation is also used to reach equilibrium point [1]

New era simulation software's provide with highly advanced and complex modeling techniques and numerical solutions including model types and relevant standards for generators, motors, protection equipment and other dynamic tools and their regulation. [6]

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

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.

Chapter #3: Load Flow Studies

3.1 Steady State Stability: Load Flow Studies foretells Power flow and voltages in different buses depending upon the status of units and Loads. Power engineers most extensively manipulate this tool. [1] Power Flow Studies gives the values of Active and reactive power, angles of phase, Voltages at different buses in transmission lines and transformers in power system in three phase equilibrium steady state condition. [2-3] the out-growth of this procedure is that apparatus losses can be calculated. Power system security, most effective power flow, state assessment and continuity of power flow are done with Load Flow studies. [4]

3.2 Load Flow Studies:

Load Flow studies is carried out in PSS®E software for ensuring whether the 132 KV Network is operating at normal level before connecting 2.69MW Machai generator and after connecting. [5] A power System is never in steady state; minor perturbations associated with changes in load and large perturbations in the form of transmission line tripping, faults, generator loop loss and large load changes occur.

Load-flow studies also known as Power flow studies deliver an Organized and rigorous close-in to judge distinct voltages of buses, phase angles, real and reactive power through various branches. Units, transmission Network, and distribution Network constitutes an electric circuit which is used for modeling electric power system. [3]

Various *operational* parameters under different conditions, such as real and reactive losses, are derived from Load Flow analysis. These attributes are important in investigation, design and comparison of different options for the connection between the grid and the hydro power plants. Additionally the network configuration and setup for the load-flow analysis will be used to form the basis for the subsequent work related to the power system [2].

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] Stability analysis of 132KV Network is done to determine whether the system is operating normally before and after interconnection. The voltage of bus & power angles is affected by power flow and vice versa.

For Load flow studies of 132KV Network of Dargai/Malakand area the Network is designed using a Graphical user interface software i.e. Power System Simulator for Engineers.

Fixed slope decoupled Newton Raphson method is employed for load flow studies of 132KV NTDC Network in PSS®E before interconnecting 2.679MW generator at Machai and after interconnection to the Network.

The best overall approach for computing power flow solutions up to and beyond the critical point is to use customary and continuity approach of power flow analysis in a reciprocal and supplementary manner.

$$F(\Theta, V) = \lambda K \dots \dots \dots (1)$$

In equation (1) a conventional method Newton Raphson Fixed slope decoupled method is used to compute Power flow solutions for successfully increasing Load levels until a solution cannot be reached.

In PSS®E Fixed slop Decoupled Newton Raphson Technique for Load flow studies with Flat start and switched shunt enabled are employed .[1]

This method is adopted because it takes lesser number of iterations and has faster convergence.

3.3 Fast Decoupled Load Flow Technique:

Power Flow study is done through different approaches .Fast Decoupled Load Flow (FDLF) [6-7] and Newton method [5] as shown in Fig 3.1 have fast convergence, better speed of calculation and moderate computer storage request. Fast Decoupled Load Technique is much quicker.

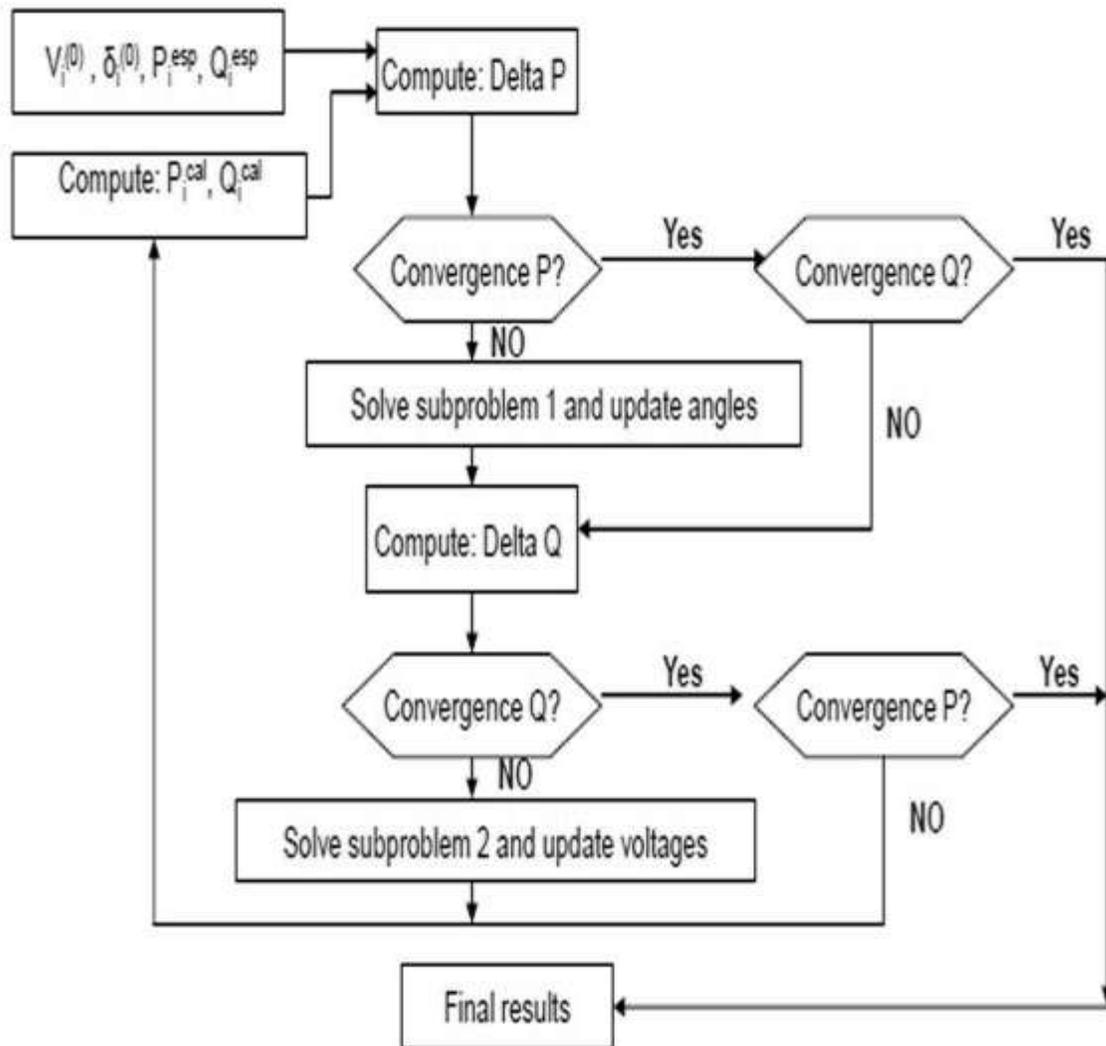


Fig 3.1: Topology for Fast Decoupled Load Flow Technique

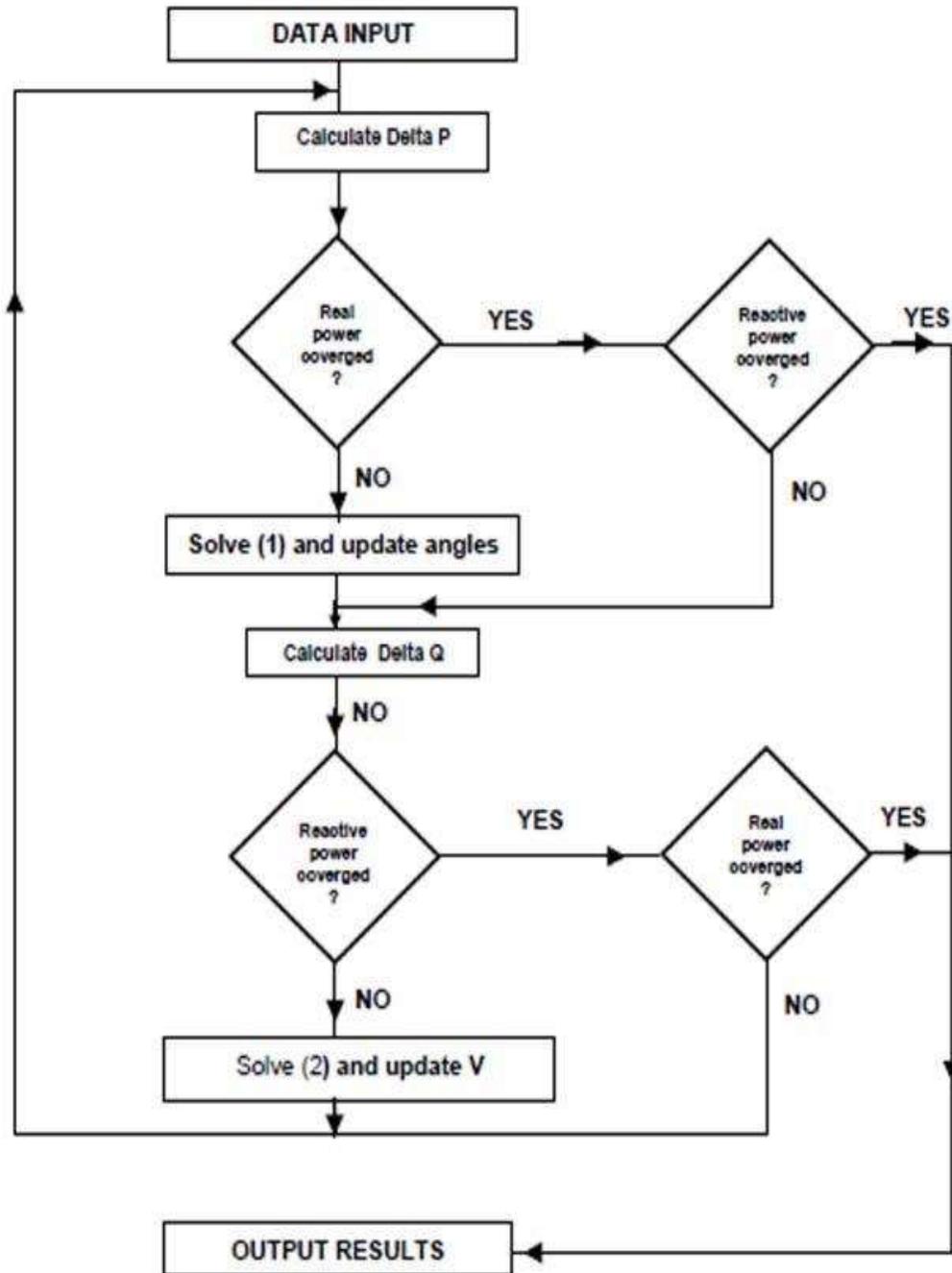


Fig 3.2: Network convergence process

The diagram in Fig 3.2 shows the algorithm execution process for Newton Raphson Fast decoupled load flow technique

It's the virtue of electrical power system that active power, P and voltage angle are proportional.

Similarly Var variations depend on voltage magnitudes. Following facts clearly signify that:

(i) The magnitude of voltage is equal to 1.0 during steady state condition.

(ii) Due to the reactive nature of transmission lines ($G_{ij} \ll B_{ij}$) where

G_{ij} =conductance

B_{ij} =susceptance

(iii) The differences in values of angles of bus voltages is minor in normal condition

($\theta_i - \theta_j \approx 0$ (within $5^\circ - 10^\circ$)).

(iv) The reactive power given to the bus is lower in value from the utilized reactive power by entities shorted with the ground.

$$(Q_i \ll B_{ii} V_i^2) \dots\dots\dots 2.1$$

The nature of the quantities $G_{ii}-G_{ij}$ and $(\theta_i-\theta_j)$ as discussed above:

$$\rightarrow J_3 \dots\dots\dots 2.2$$

$$\rightarrow J_2 \dots\dots\dots 2.3$$

Putting values from eq 2.2 and 2.3 in eq 2.1 we get:

ΔP depends only on $\Delta\theta$ and ΔQ depends only on ΔV . Thus, there is a decoupling between ' $\Delta P - \Delta\theta$ ' and ' $\Delta Q - \Delta V$ ' relations.

One of the most effective and wide-ranging used forms of energy is Electrical energy. Power System generates and transmits electrical energy. Electrical Power System consists of three Parts: Generation, Transmission and Distribution.

These three parts work together with one another to make sure a reliable and effective operation. Electrical Power System has been greatly modified to fulfill the energy demands of the world with respect to time.

In Electrical Power System the Progressive development of Network is a complicated procedure. For the safety, reliability and smooth operation Power engineers have to keep all variable in proper limits to meet the challenges due to number of apparatus and interconnection of Power System.

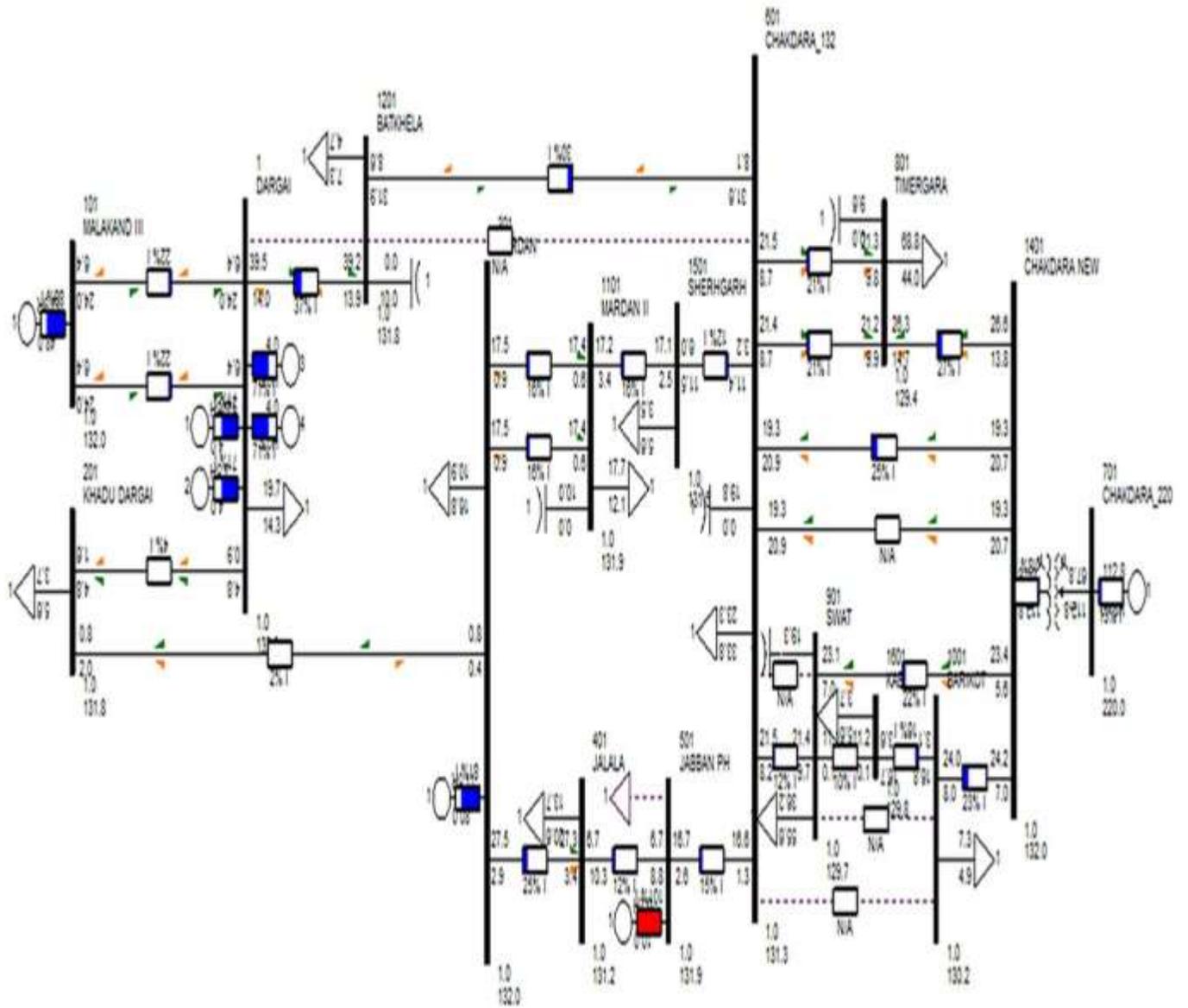


Fig: 3.4: Animated Current Flow Check on Network before the interconnection of new generator to bus 1101

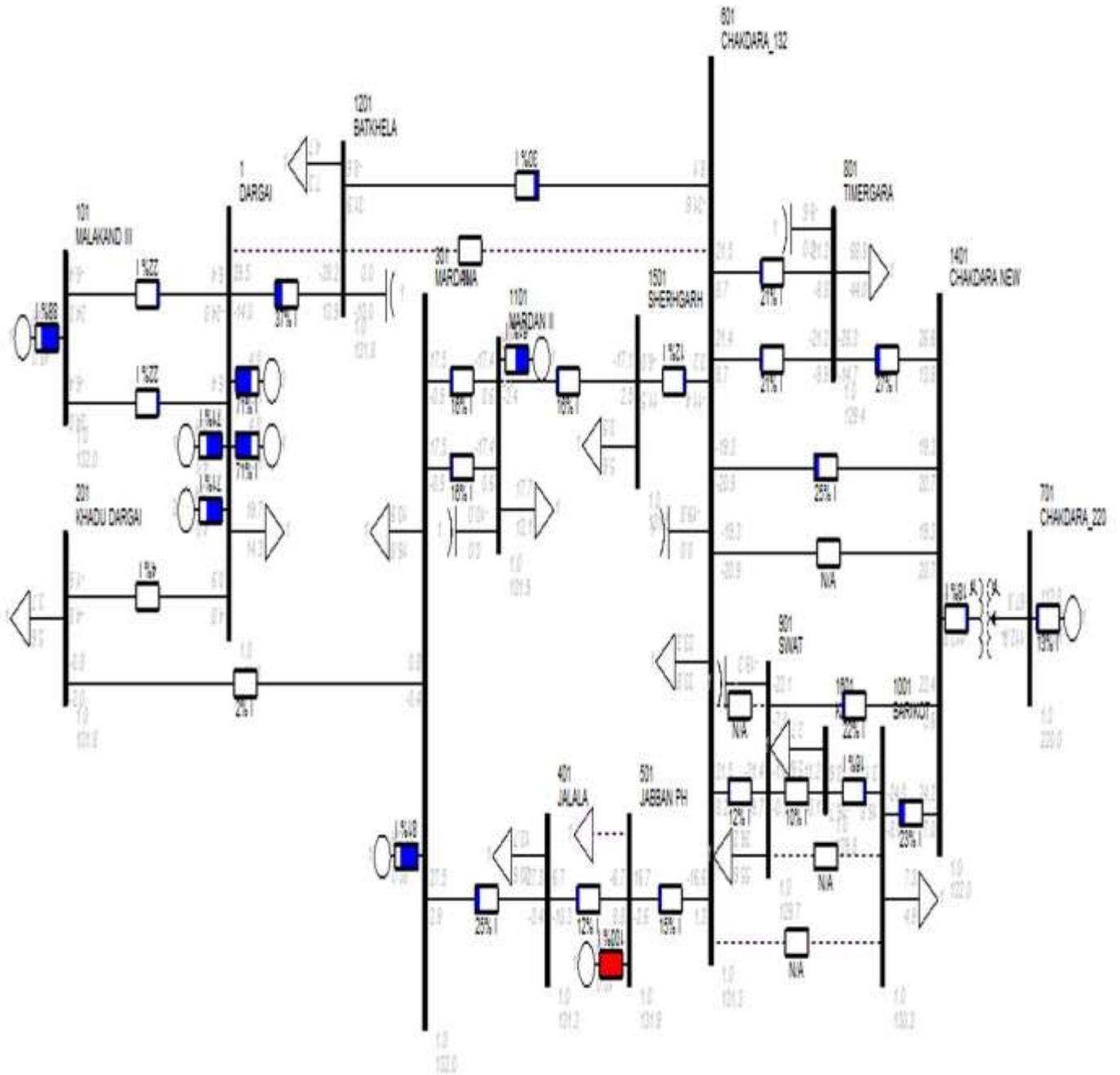


Fig 3.5: overloading condition check after connecting generator to Mardan II bus 1101

Chapter #4: Dynamic simulation of 132 KV Network

4.1 Dynamic Stable State:

Transient state is also called as contingencies conditions. Power System which is stable under transient and steady state is termed as a good system. In case of any disturbance absence of one type of stability for example transient stability leads to contingency condition. Monitoring and Protection is very important to solve challenges in the way of stability.

Dynamic stable state has great importance for the conservation of Security of Power system. For example occurrence of fault must not cause units tripping because of loss of synchronism and the cascaded outage causing blackout. Transient stability is a function of disturbance. The power requirements cannot be compensated on immediate basis by prime-mover when a sudden perturbations e.g. short circuit, changes in load, switching out of loaded circuit occurs. For giving back stasis to the system movement of rotors of synchronous machines connected in the Network to comparatively new angular positions causes fluctuations of angle, power and current .this angular movement has severe repercussions on the synchronism of machines to misplacement of synchronism. This is called transient instability. [6]

4.2 Impact of System Characteristics:

Commanding system Characteristics that have direct impact on Dynamic stability are:

1. Generator reactance and inertia
2. Transmission system reactance under normal and contingency (post fault) condition

4.3 Three phase fault:

Transient stability standards encompasses the capability of the system to cope with three phase bus fault at crucial sites such as terminals of exceedingly loaded generators and lines transporting

ample quantity of power. 3- ϕ faults has quite arduous impact on power system. The Value of T_c which is critical clearing time on generator HV side can be calculated as:

$$T_c = k$$

K is a constant, x_t is transformer reactance, x_d is synchronous reactance and x'_d is transient reactance. Transient stability is improved by increasing H : inertial constant in MJ/MVA and reducing the reactance. [8]

4.4 IEC-60909 Fault Analysis Techniques:

IEC stands for (International Electro technical Commission). IEC 60909 is a technique for balance and unbalanced short circuit calculation .e.g.

1. 3-phase fault, line to ground fault.
2. Total fault current with thevenin impedance set.

As per the specified criteria a voltage source is represented at the fault point. According to Thevenin's theorem an electrical circuit can be represented with voltage source called thevenin's voltage V_{th} and impedance Z_{th} connected in series. The value of V_{th} is same to the voltage value before fault. The series impedance, which is called the Thevenin impedance, is the impedance seen from the location of the fault. The series impedance Z_{th} is the thevenin impedance at the point of fault.

The fault current is then given by: $I_f =$

In more complex Networks thevenin voltage is calculated with the help of Load Flow Procedure. By partially inverting the admittance matrix the value of admittance matrix is calculated. In a Specialized packaged software e.g. PSS®E 132KV NTDC Network has been devised to do

calculations with precision and efficiency. Calculating fault current for different functional arrangement of Network and their units is far easier.

3. Tap ratios unchanged and phase shift angles set to zero. The angle shift of Transformer is kept at a zero value. The impedance of transformer depends upon phase shift angle and its set at nominal value.

4.4.1 Single line to ground(S-L-G) fault:

These faults are most prevalent in HV and EHV lines. When the equilibrium of Network is affected such disturbances are called unsymmetrical faults. Most commonly occurring unsymmetrical fault is SLG fault. 75% of faults occurring in a system are S-L-G **faults**. Most of the faults on a transmission lines occur when they are exposed to rigid environment. Lightning strokes can create flashover of line insulators, high speed winds may lead to tower failure, ice loading and wind can result in mechanical failure of line or insulator and tree branches may cause short circuit. The faults on cables, circuit breakers, generators, motors and transformers are less frequent.

Two types of faults take place in a power system:

1. Shunt faults
2. Series faults

Single line to ground fault is one form of shunt faults. This fault occurrence takes place due to falling of conductor to ground or connection with neutral wire .Falling trees due to storm, strong winds and heavy rain causes SLG faults. [9]

1. Back-up protection is used for removing single line to ground fault.

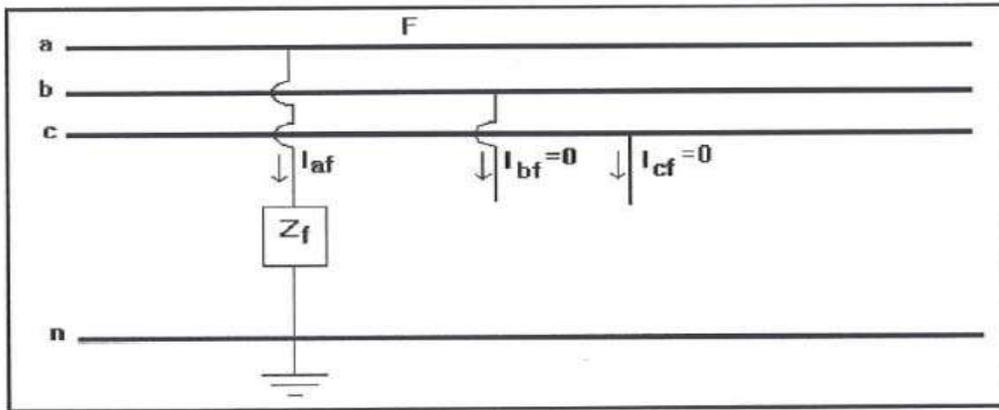


Fig 4.1: S-L-G Fault

In a 3- ϕ four wire transmitting circuit LG fault through impedance Z_f at faulted site denoted with F is shown in Fig 4.1. marking of the phases is done in such a way that fault occurrence is on phase a:

The currents through the two phases a and b can be described as under at the location of perturbation:

$$I_b=0 \quad \dots\dots\dots (i)$$

$$I_c=0 \quad \dots\dots\dots (ii)$$

$$V_a = Z_f I_a \quad \dots\dots\dots (iii)$$

The symmetrical components of the fault currents are:

$$=$$

From which it is easy to see that:

$$I_{a1}=I_{a2}=I_{a0}= I_a \quad \dots\dots\dots iv$$

Expressing eq iii in symmetrical components:

$$V_{a1} + V_{a2} + V_{a0} = Z^f I_a = 3Z^f I_{a1} \dots\dots\dots v$$

Eq (iv) and (v) shows sequence currents as same and the summation of sequence voltages equal to $3Z^f I_a$.

Impedance $3Z^f$ should be used as base for the series connection of sequence as shown in Fig 4.2.

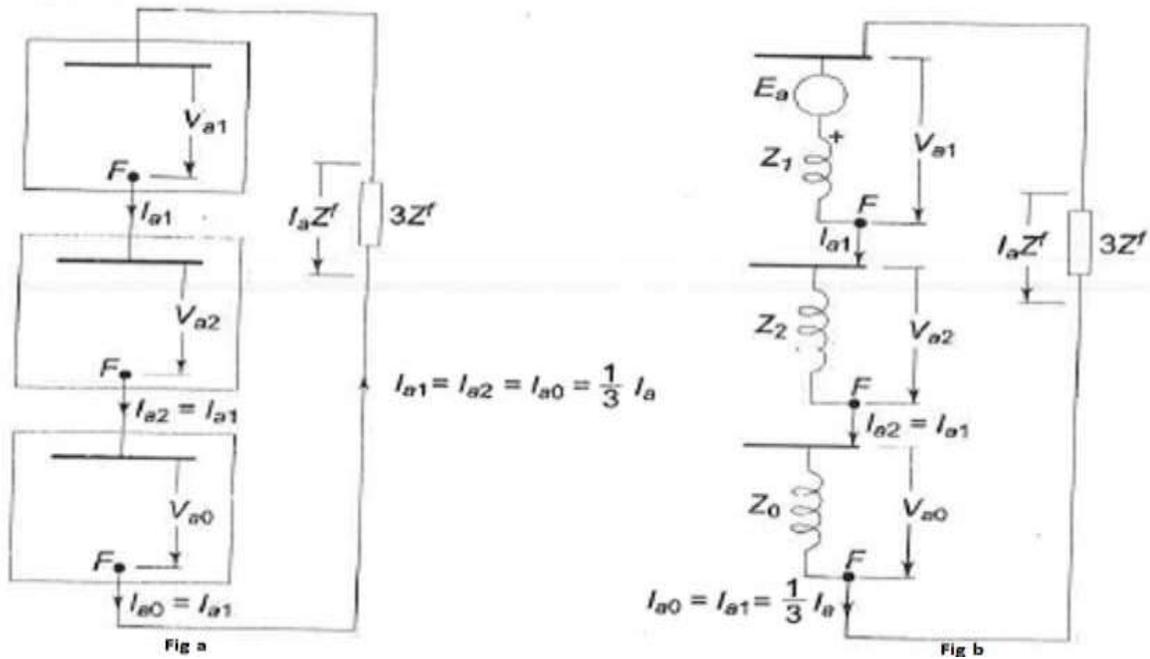


Fig 4.2: Connection diagram of sequence Network for an (L G) fault

Fig b can be written in thevenin equivalent format as:

$$I_{a1} = \dots\dots\dots vi$$

Fault current I_a is given by:

$$I_a = 3I_{a1} = \dots\dots\dots vii$$

The voltage of line b to ground underneath fault estate:

$$\begin{aligned} V_b &= \alpha^2 V_{a1} + \alpha V_{a2} + V_{a0} \dots\dots\dots viii \\ &= \alpha^2 (E_a - Z_1 I_a) - Z_2 I_a - Z_0 I_a \end{aligned}$$

Replacing the value of I_a from eq vii and re-arranging:

$$V_b = E_a \dots\dots\dots iv$$

The expression for V_c can be similarly obtained.

Probability of occurrence of single line to ground faults is 70%.

4.4.2 Three Phase (3 Φ) Faults:

Fault is coincident on all three phases in 3-phase faults. The analysis of Network is carried out on per phase base due to balanced condition as other two phases carry equal current having a phase shift of 120°. The simulation of fault in Network is carried out by connecting impedance at fault point using Thevenin's equivalent Network. It's easy to utilize the impedance matrix of a bus because analysis of various buses shows Thevenin's impedance as the diagonal elements of a matrix during fault analysis. It's necessary for per phase Network Model that the system remains in steady state. A fixed value voltage source is used for the representation of generator at the back of reactance that may be sub-transient, transient and regular d-axis reactance. As there's no extra node in π -Model of Transmission line therefore all impedances are represented by a common point. Three phase faults are cleared by primary protection as shown in Fig 4.3.

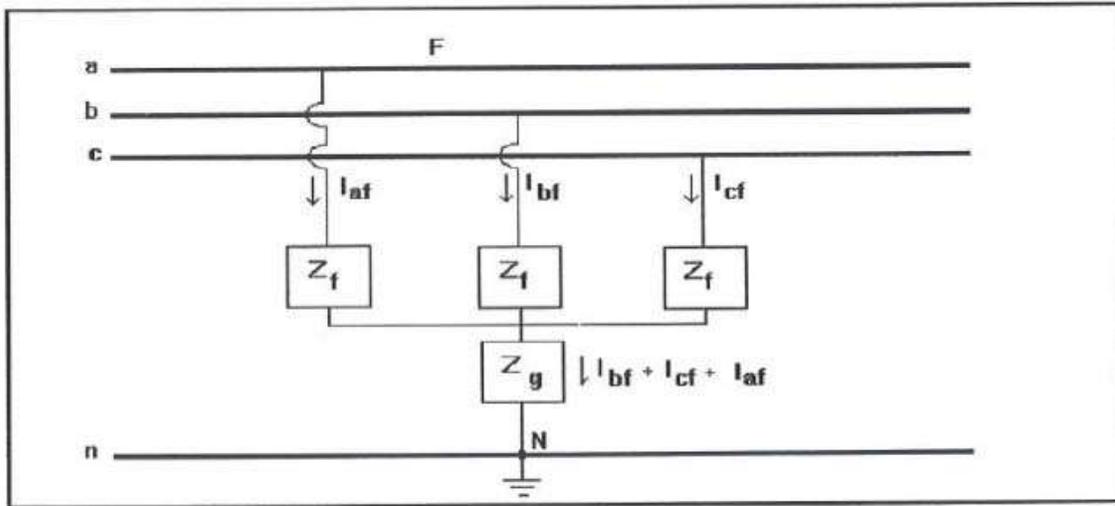


Fig 4.3: Three-phase fault

4.4.2.1 Symmetrical (three phase) fault:

Ample amount of unbalanced single phase loads causes unbalanced operation of power system which is then analyzed on 3- ϕ basis.

This method is called symmetrical component analysis where the three phase voltages and currents are represented with stasis array of voltages and currents.

The impedances of different power system components for example synchronous units, transformer lines are converted to symmetrical components by decoupling it; which produces an independent network for each entity (balanced state).

Typical relative frequency of occurrence of Three Phase faults are 5%. [9]

4.5 Dynamic Simulation of 132 KV NTDC Network:

Dynamic simulation purpose is studying particular voltage collapse situation, coordination of protection and control; including generating unit and Transmission Network protection and control e.g. Generator excitation Protection, Armature Over current protection, Transmission Line Over current protection, Capacitor Bank controls, phase shifting regulators and under voltage load shedding. Dynamic simulation aim is finding out the way of reaching balanced state. [1]

New Era simulation software's like PSS®E provides complex and precise procedure including types of model and related standards for units, motors and protection devices with regulation [6]

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

For selecting proper circuit breaker rating, relay settings, coordination and fault analysis

Simulating the Network in PSS®E and its transient studies are carried out.

For selecting proper circuit breaker rating, relay settings, coordination and fault analysis i.e. simulating the Network in PSS®E transient studies are carried out.

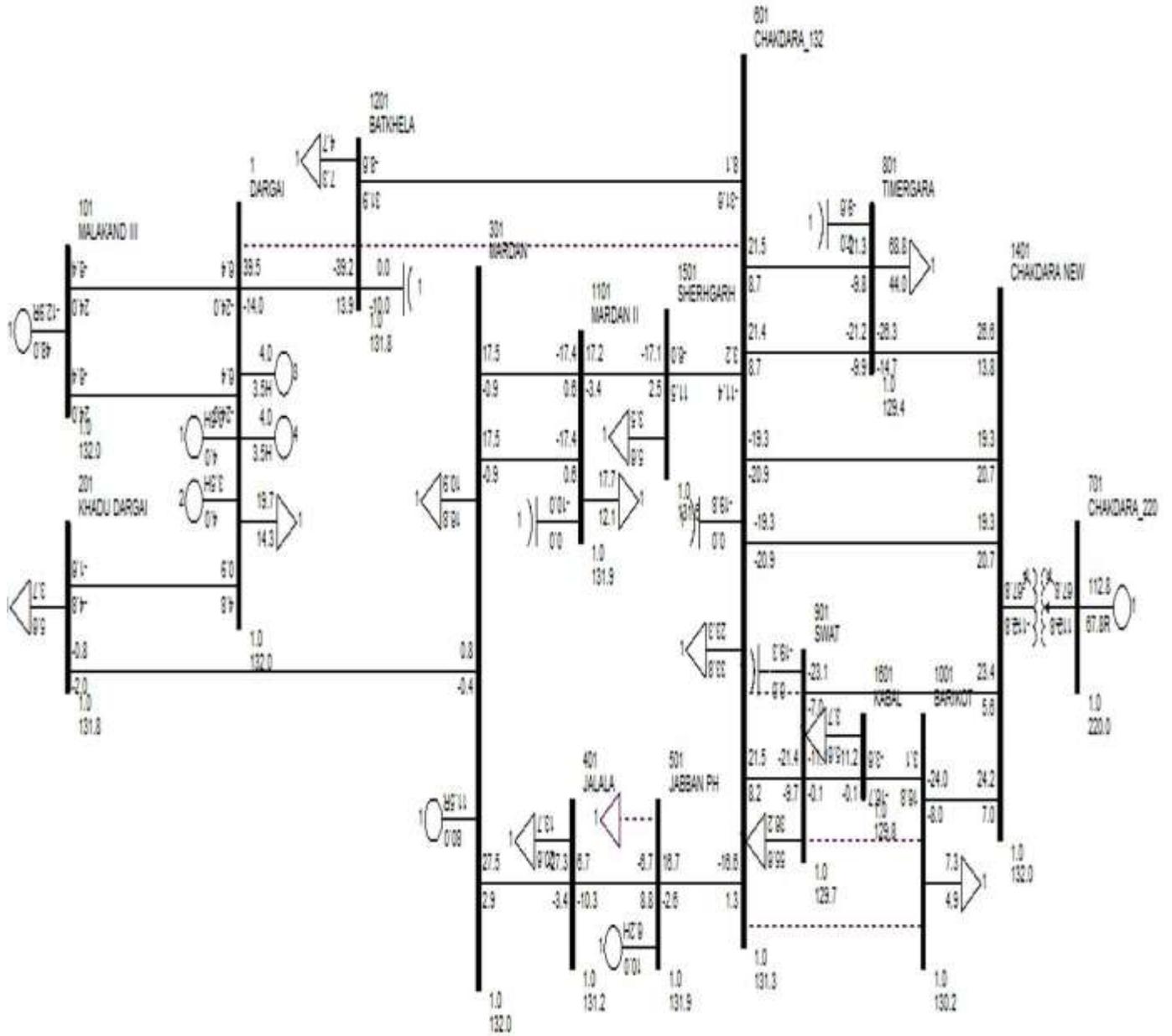


Fig.4.4: One Line Sketch of 132 KV NTDC Network

SLD of 132 KV Network as shown in Fig 4.4 has been drawn in PSS®E with the help of Machine/Generator Data, Transmission lines, branches and Load data.

A reference bus is one to which a bigger size generator is linked in a Transmitting Network. The generator rating has been taken very high for putting a limit on the Network by taking Chakdara 220 KV bus as a reference.

The Load at JALALA shown with a dotted line is non-inertial Load.it shows the Renewable Energy Load in P and Q form taken as negative.

4.5.1 Angle Plot at Mardan II:

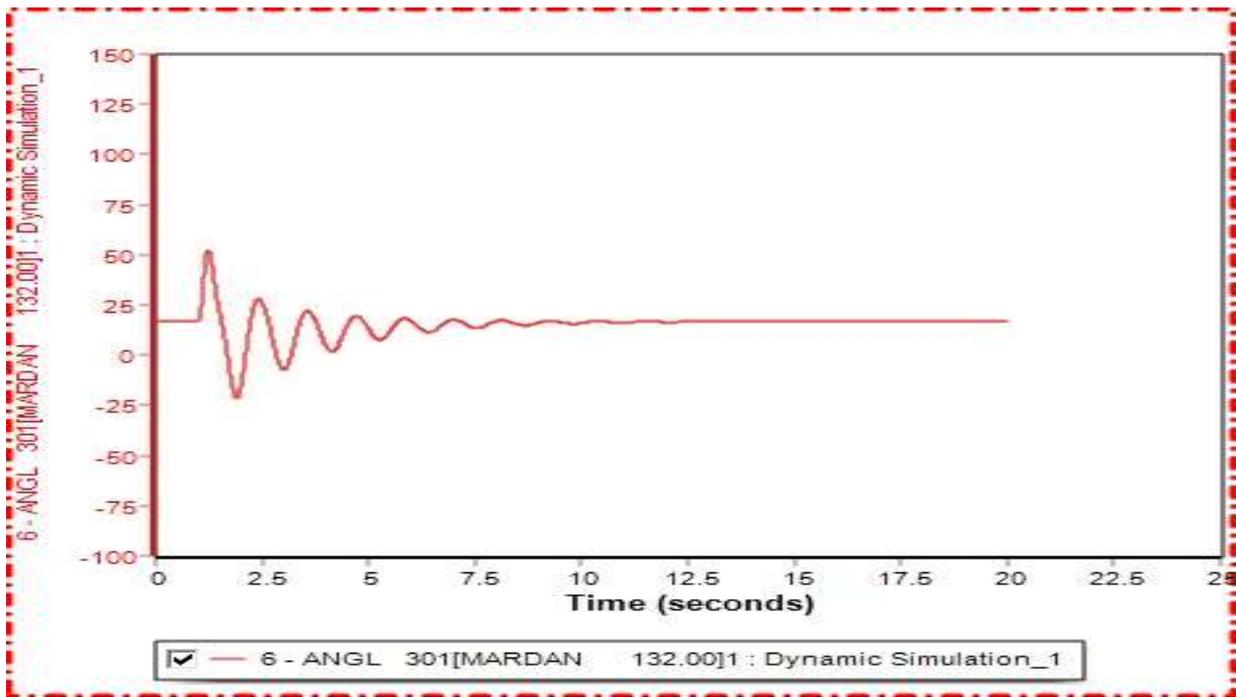


Fig 4.5.1: angle plot at Mardan II Generator connected at Machai

Fluctuations in the unit rotor angle at bus 1101. Application of fault is done at $t = 1.1\text{sec}$ and cleared at $t = 1.16\text{sec}$.

Machai Generator 2.6MW is connected to Mardan II and Load flow studies were carried out in PSS®E. The system got converged. Dynamic simulation of the Power Network was carried out and fault was applied at Mardan II and all buses in the Network during simulation for 1.1sec (5-Cycles)and cleared at 1.16 sec (8-Cycles).The Angle plot shows oscillations in sub transient region and a straight line in steady state region at 20s.

It shows a safe synchronizing operation of Machai generator to the Network.

4.5.2 Angle plot of Swing Generators/Chakdara in the Network after connecting Machai Generator to Mardan II:

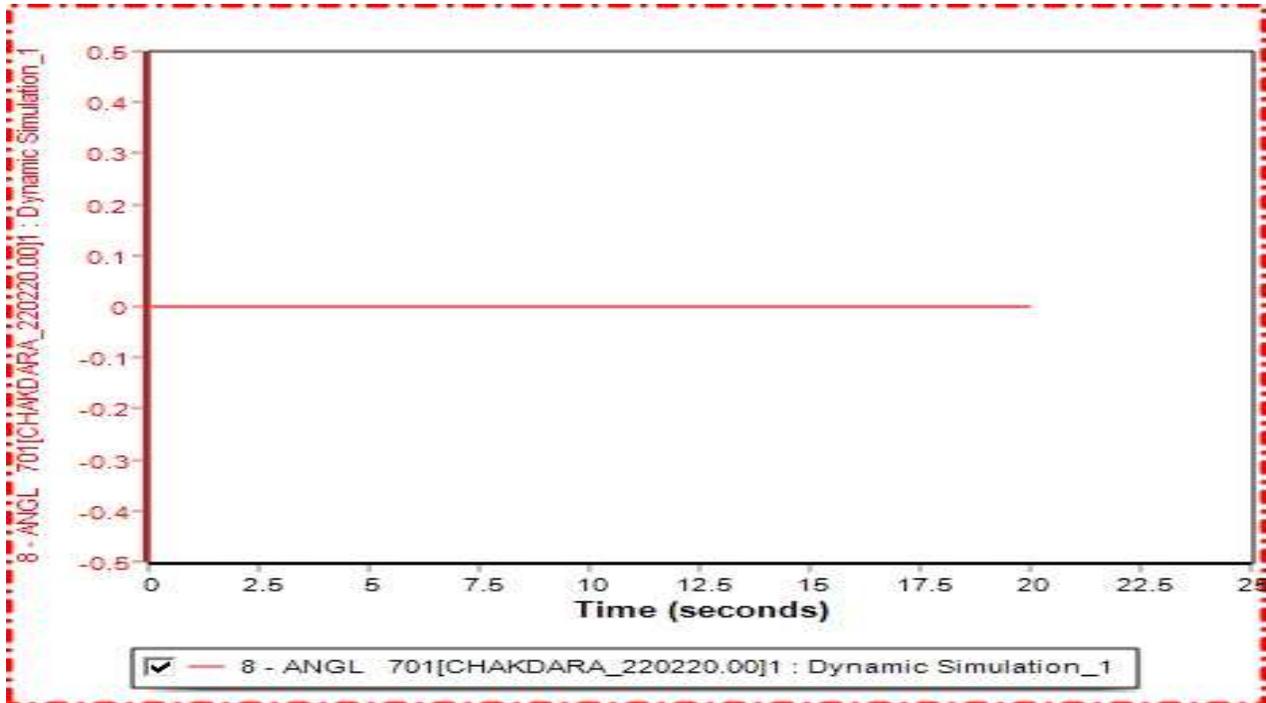


Fig 4.5.2: Angle plot at Chakdara Generator

Variations in the rotor angle of generator at bus 701 when a fault is applied at $t = 1.1s$ and cleared at $t = 1.16s$.

For the appraisal of transient stability power angle reference is substantial because due to perturbations power system operation underneath steady state becomes significant. [7]

Chakdara 220 KV has been taken as a reference for power flow studies in PSS@E.

During Dynamic Simulation of 132KV Network the angles of all other machines/generators connected in the network have been calculated with respect to Chakdara 220 KV.

The angle plot of the reference bus is a straight line; it is clear from the plot that the reference remains the same for the angle plot of all machines connected in the Network.

Chakdara 220KV sets a voltage angle (delta) reference for all other buses in the system during simulation.

The streaming of Active and reactive power in a transmission line hinges on the voltage angle difference between the two buses and hence the actual voltage angle is insignificant. For the same reason the delta of the slack bus can be assumed of any value. But it is usually assumed as zero degrees just for the sake of convenience.

The angle at Slack bus is kept constant and real power is kept varying to make up for losses during load flow studies. [5] The sum of active power P injected in the Network and the sum of active power expelled from the Network combined with losses in the line usually copper losses is entrusted to Slack bus. the network configuration and setup for the load-flow analysis has been used to form the basis for the subsequent work related to the power system [12].

Power for slack bus = Total Power going into the system - Total Power going out of the system
Transmission +line losses

The slack bus generator Chakdara 220KV supply the active power required to balance the System.

4.5.3 Angle plot of Dargai Generators/Machines in the Network after connecting Machai Generator to Mardan II:

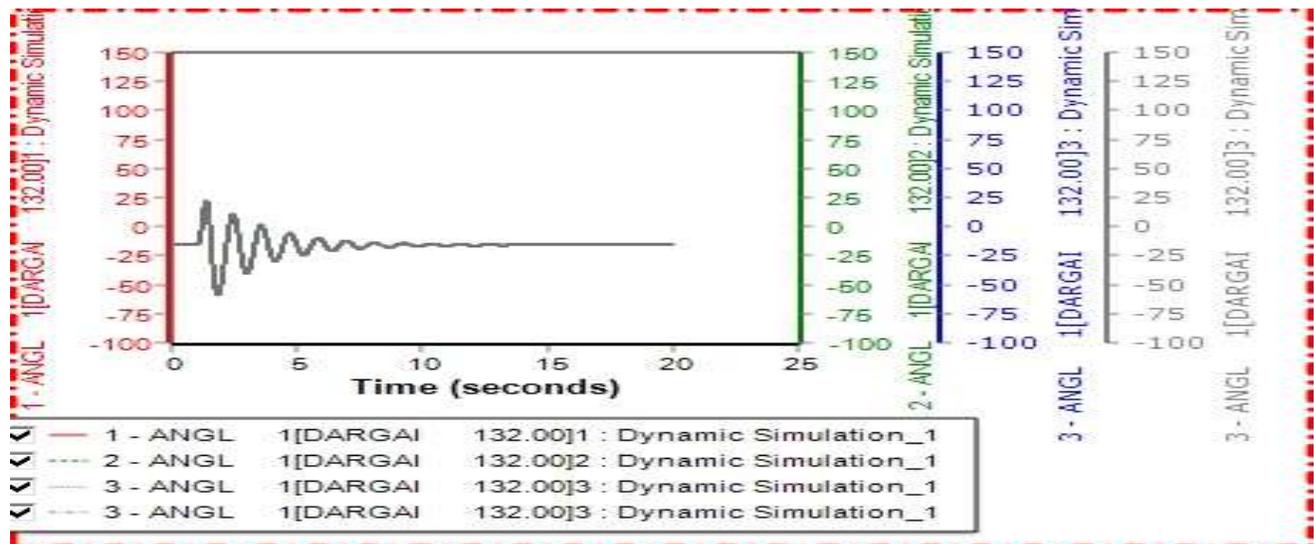


Fig 4.5.3: Angle plot at Dargai Generators

Oscillations in the rotor angle of units at bus 1. When a fault is applied at $t = 1.1s$ and cleared at $t = 1.16s$

Once Dynamic Simulation is carried out in PSS@E for 132kV NTDC Network, angle plot of All the Machines Interconnected in the Network was obtained.

It can be seen clearly from the angle plot that the rotor angle of generator becomes stable after 7.5 seconds at this point stability is reached after applying fault for 1.1sec and clearing it after 1.16 sec during dynamic simulation of the Network. The Plot shows 5-Cycles time for applying fault on any bus in the Network for example Mardan II as per NEPRA standard. The fault application adds shunt to the bus to absorb the reactive power so that voltage decreases at the point of fault and so does the current. The angle plot of Machines shows oscillation in Sub transient period and

the degree of oscillations decreases in the transient period till the steady state region where we obtain a straight line.

4.5.4 Angle plot at Malakand III Power plant:

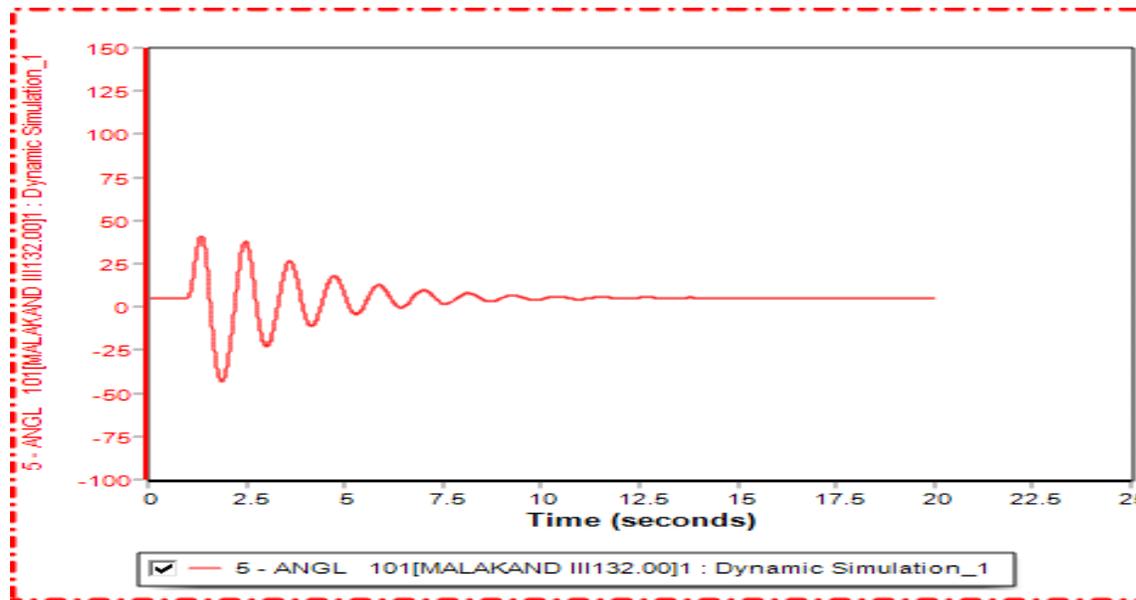


Fig 4.5.4: Angle plot at Malakand III Generators

Oscillations in the rotor angle of generator at bus 101. Following a fault which is applied at $t = 1.1s$ and cleared at $t = 1.16$ during simulation.

The Angle plot of Malakand III 81 MW connected in the Network also clearly shows a stable synchronizing operation for Machai Generator.

4.5.5 Angle Plot of Jabbah Power House:

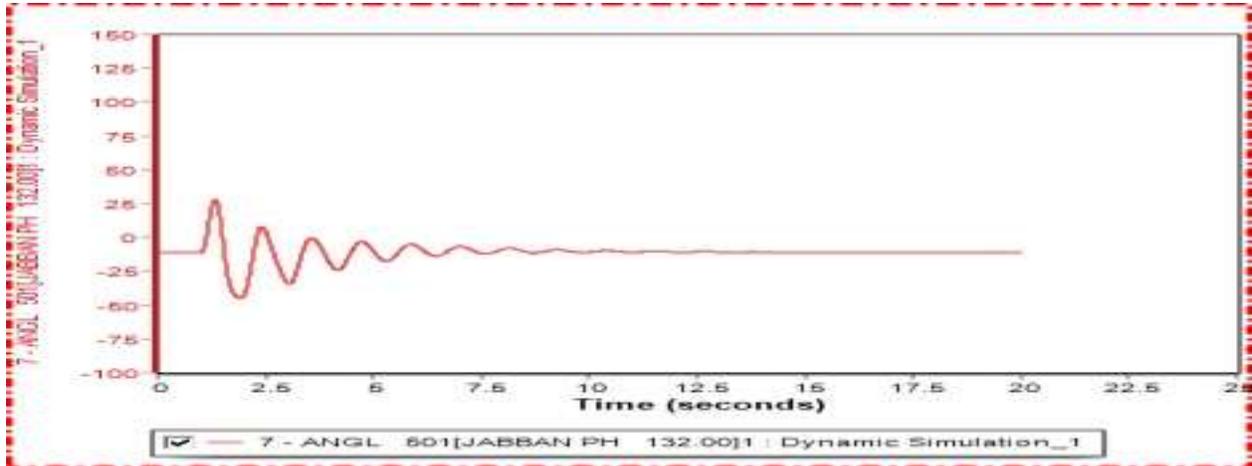


Fig 4.5.5: Angle Plot at Jebbah Power plant Generator:

Faults have been applied at all buses in the Network for 5 Cycles as per standard by NEPRA and then cleared after 1.16 sec (8-Cycles) time interval. The angle plot of Jabbah shows straight line at 20 sec time interval.

4.5.6 Power Plot of Mardan II:

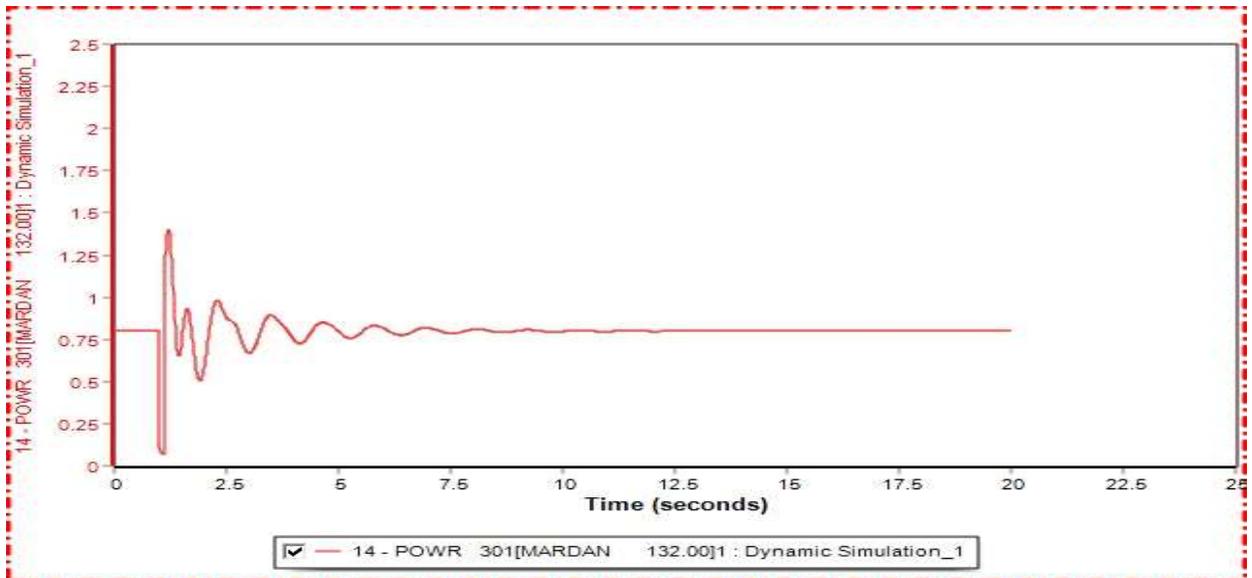


Fig4.5.6: Power Plot at Mardan II

Oscillations in the rotor angle of generator at bus1101.Following a fault which is applied at $t = 1.1s$ and cleared at $t = 1.16s$

The power plot of Mardan II bus show major fluctuations up to a time period of 1.1 sec (5-Cycles) i.e. in the sub transient region there are major fluctuations and in the transient region the amplitude of these fluctuations decreases and dies out in the steady state region.

This analysis proves that interconnecting generator of 2.679MW to the 132KV Network is no threat to the stability of the Network.

4.5.7 Power plot of Chakdara 220 KV Grid:

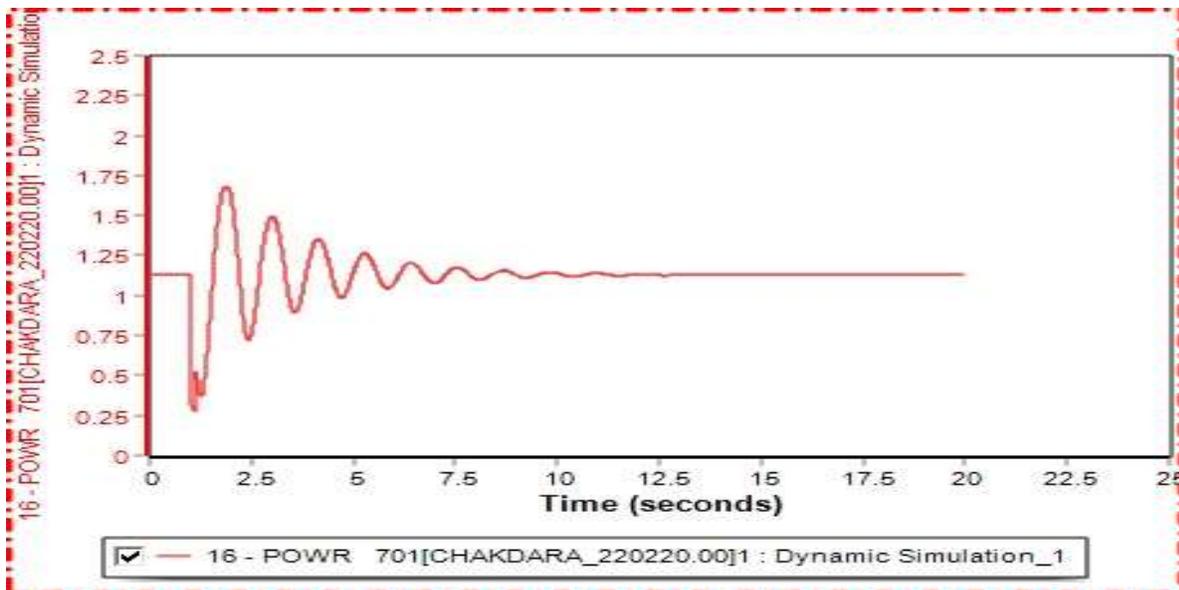


Fig 4.5.7: Power plot at Chakdara Generators

Oscillations in the rotor angle of generator at bus 701. Following a fault which is applied at $t = 1.1s$ and cleared at $t = 1.16s$

Power plot of Chakdara 220KV shows major oscillations in the sub transient region that dies out in the transient region at 20s duration. The fault is cleared from all buses after connecting generator to Mardan II.

4.5.8 Power Plot of Dargai Machines in the Network after connecting Machai Generator to Mardan II:

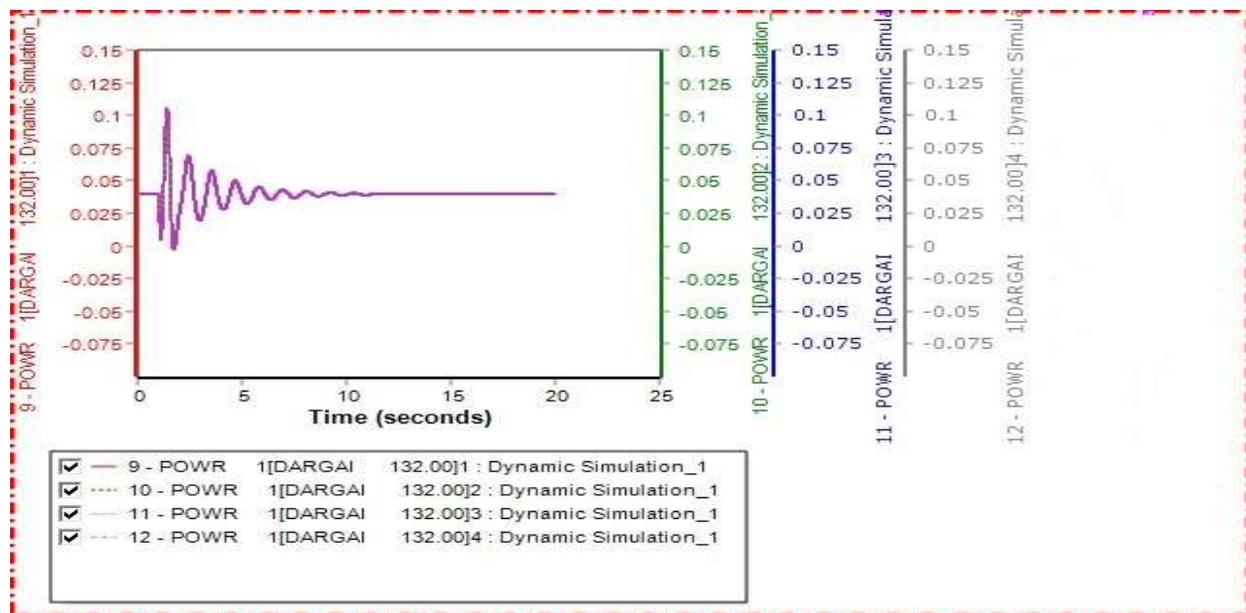


Fig 4.5.8: Power Plot at Dargai Generator

The Power Plots of Machines in the 132KV Network taking Chakdara 220 KV as a reference have been drawn in PSS®E. It can be seen clearly from the plots that Chakdara 220 KV is a straight line in the sub transient, transient and steady state region. While other machines in power plants

including Dargai, Malakand III, Mardan, Jabban PH and Mardan II shows oscillations in the sub transient region which dies out in the steady state region.

The fault was applied for 1.1s duration during simulation at all buses in the Network and cleared after 1.16 second in stuck breaker condition. Dynamic simulation results for the Power plots of Dargai Machines as shown in Fig 4.5.8 shows that the generators are stable even after applying and clearance of fault.

4.5.9 Power Plot at Jabbah Power House:

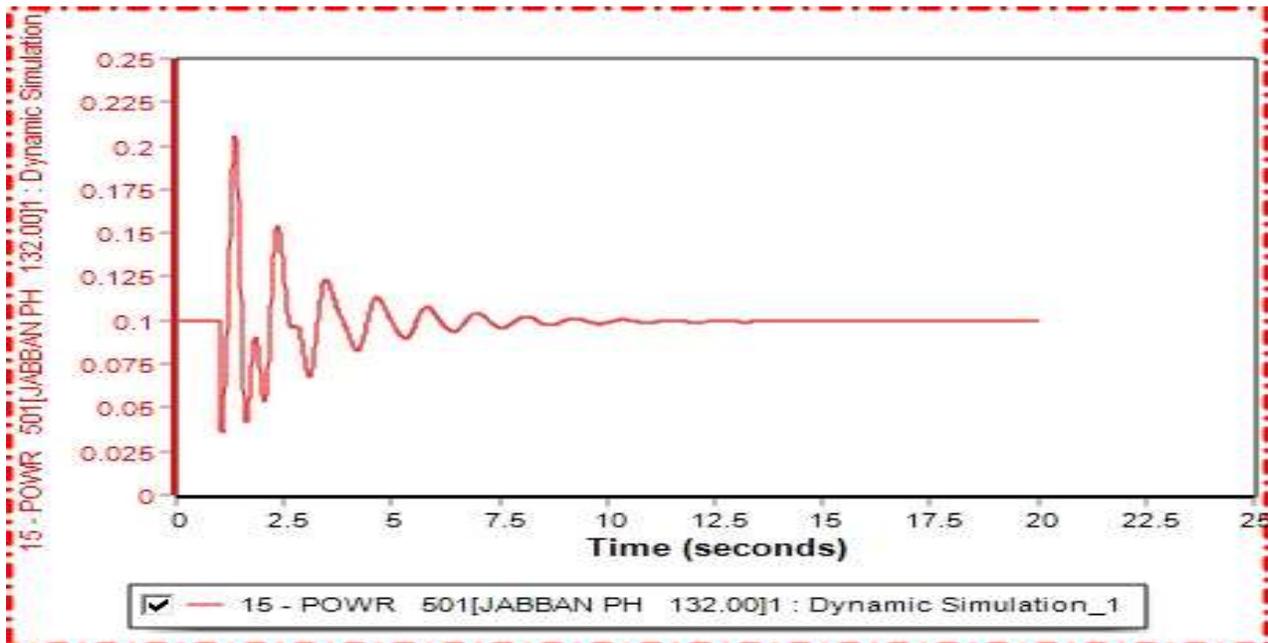


Fig 4.5.9: Power plot at Jebbah Generators

Oscillations in the rotor angle of generator at bus 501. Following Fault which is applied during simulation at $t = 1.1s$ and cleared at $t = 1.16s$ (Delayed Clearing Time)

Dynamic simulation /transient studies of jabbah power house shows fluctuation in the sub transient region for 5-Cycles as fault has been applied for the specified time. And clearing time of fault was set to 1.16 sec during Network simulation in PSS®E. The power plot shows little fluctuations in the transient period and in the steady state period the fluctuations dies out at 20sec.

Fault analysis as per IEC-60909 technique is carried out for circuit breaker time setting and relay collaboration. For this the Power Network is simulated in PSS®E and transient studies/Dynamic simulation is carried out.

4.5.10 Terminal Voltage plot at Mardan II:

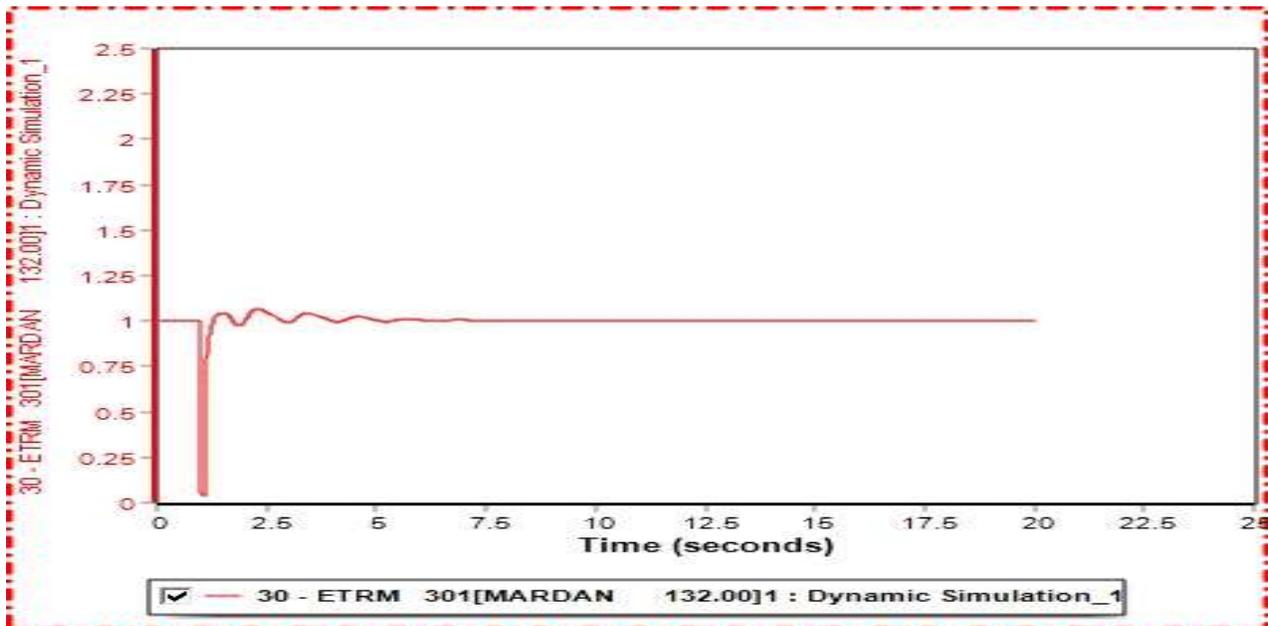


Fig 4.5.10: Terminal Voltage plot at Mardan II Generators

Oscillations in the rotor angle of the embedded generator at bus 1101. Following a fault which is applied at $t = 1.1s$ and cleared at $t = 1.16s$ (8-Cycles standard)

Due to extensive perturbations and ample load augmentation in a heavy strained power system; voltage collapse occurs. That voltage drop is followed by increased Var Utilization, that decrease in Voltage initializes load downscale causing the control to operate for revitalizing the load. For the Dynamic simulation of 132KV Network under large disturbances such as LG perturbations are more conventional on High Voltage and Extra High Voltage to an extent of 70% and 3- ϕ occurrence is 5% ;Network is simulated and Analyzed for Short Circuit in PSS@E. For Short Circuit Analysis using IEC-60909 technique different parameters were set as:

1. Tap ratios are unchanged and phase shift angles set to zero.
2. Transformer phase shift angles are kept at zero value.
3. Transformer impedance that depends upon phase shift angle is kept at nominal estimate.[8]For the Dynamic stability analysis of the Network in which 2.679 MW generator of Machai HPP is connected to Mardan II the criteria for system stable operation was withstanding 3- ϕ faults at the terminals of generator and lines capable of carrying large amount of power.

Three phase faults are more severe and S-L-G are more prevalent so the Network has been simulated for these two faults. The Terminal voltage plot clearly shows fluctuation till 5-Cycles and at 20 sec time the plot shows a straight line. It means that 132Kv Power network can with stand S-L-G faults and three phase faults. Similarly the terminal voltage plots of other machines interconnected to the Network also fulfilled the stability criteria as set for Mardan II to which new generator were connected

4.5.11 Terminal voltage plot at Chakdara:

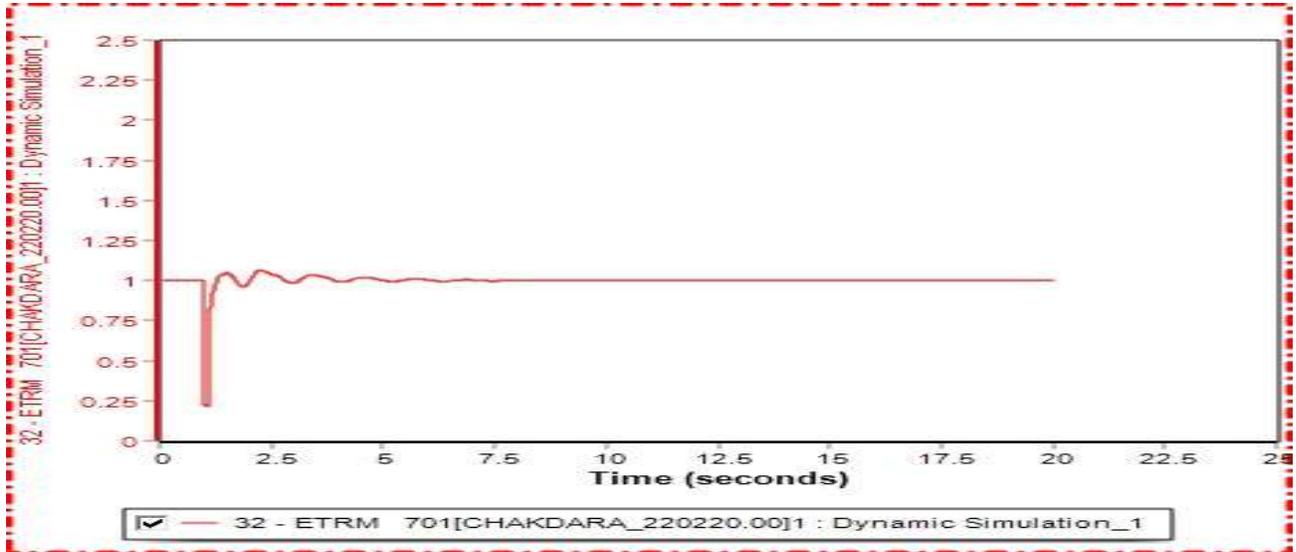


Fig 4.5.11: Terminal Voltage Plot at Chakdara Generator

Chakdara 220KV to which large generator/swing is connected to limit the Network has been taken as a reference for the dynamic simulation of 132KV Network. The terminal voltage plot is fluctuating at 5-Cycles interval due to fault and the fault removal makes the plot a straight line after 20 sec.

4.5.12 Terminal Voltage Plot at Dargai Machines:

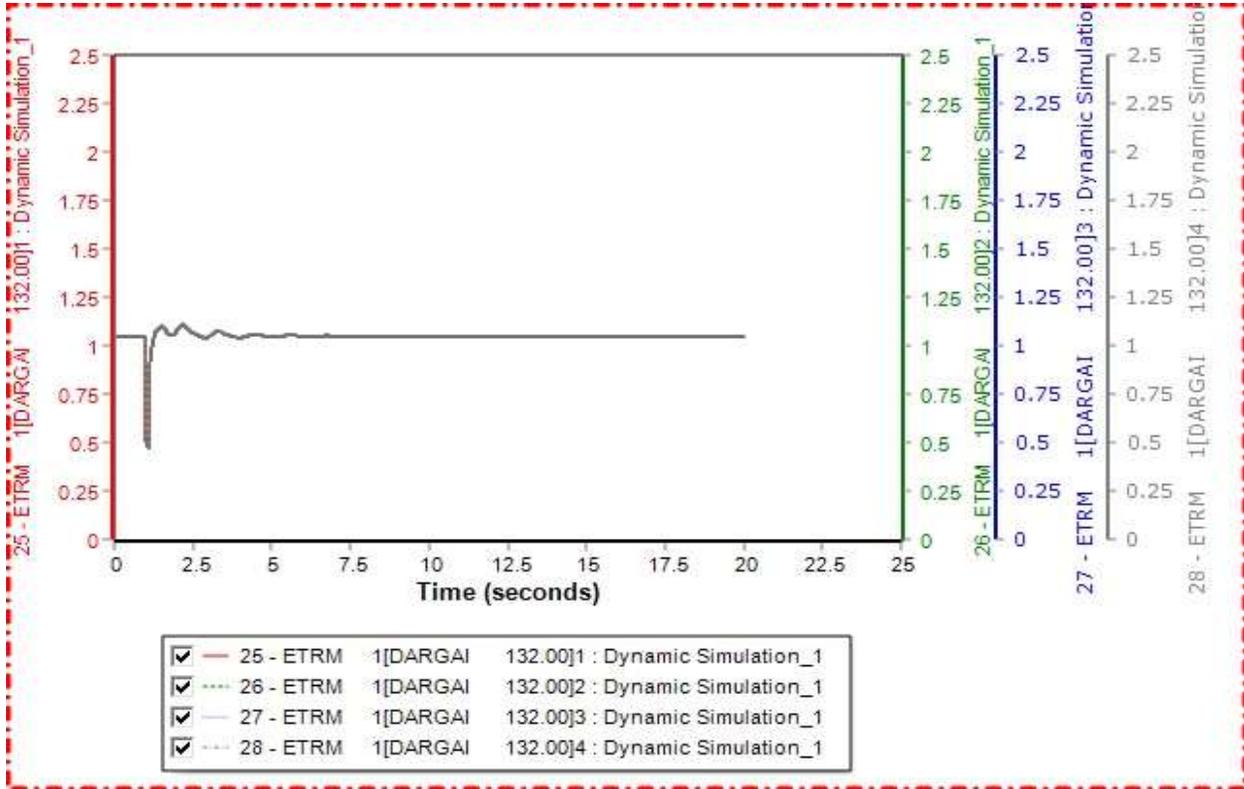


Fig 4.5.12: Terminal Voltage Plot at Dargai Generator

The plot is sinusoidal fluctuating when three phase and S-L-G faults are applied at 5-Cycles and is a straight line at 20 sec. The plot fulfills the stability criteria for voltage set during dynamic simulation. In a large interconnected power system voltage instability may occur while rotor angle stability is still maintained and generator continues to remain in synchronism. Energy import and export occur according to grid demand. [11]

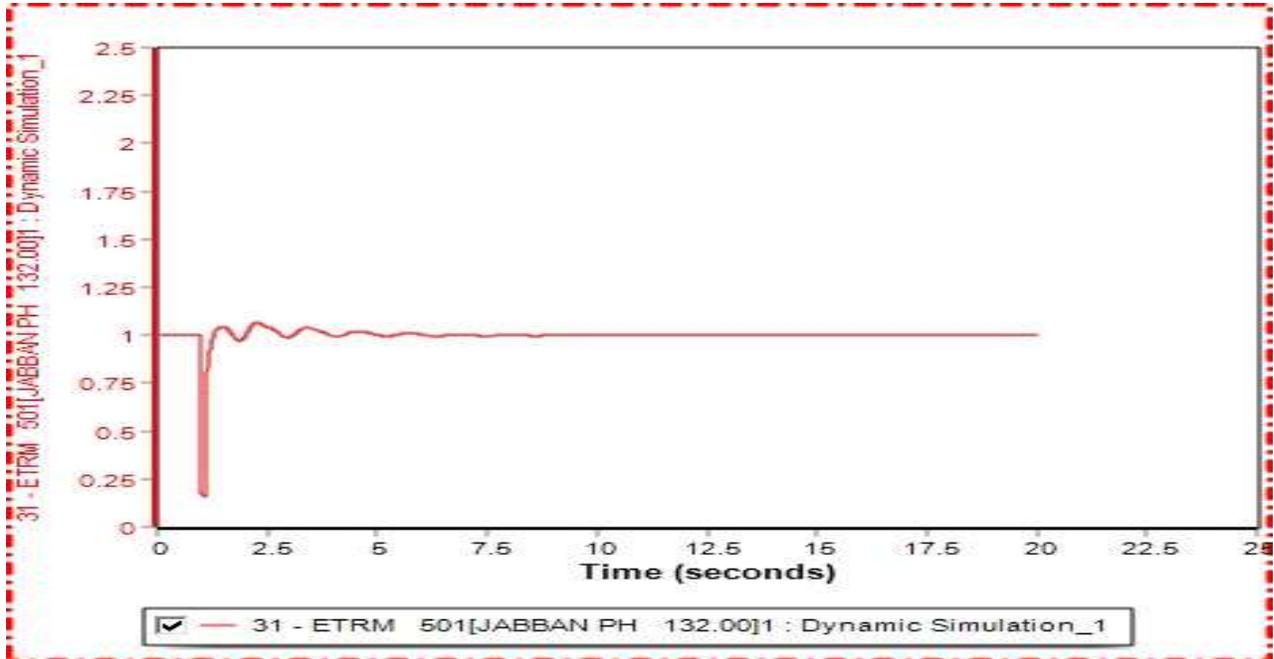


Fig 4.5.13: Terminal Voltage at jabbah Power Generator

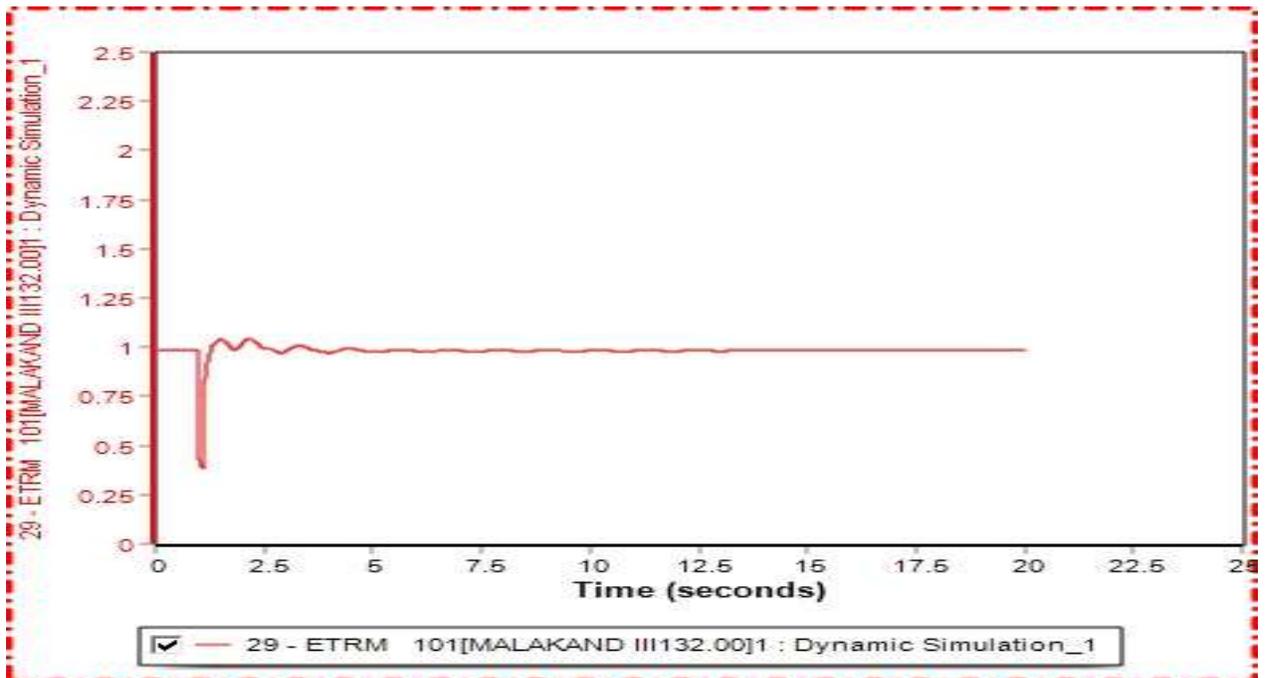


Fig 4.5.14: Terminal Voltage at Malakand III

4.5.15 Electrical power generated and Reactive power at Malakand III and Mardan grid:

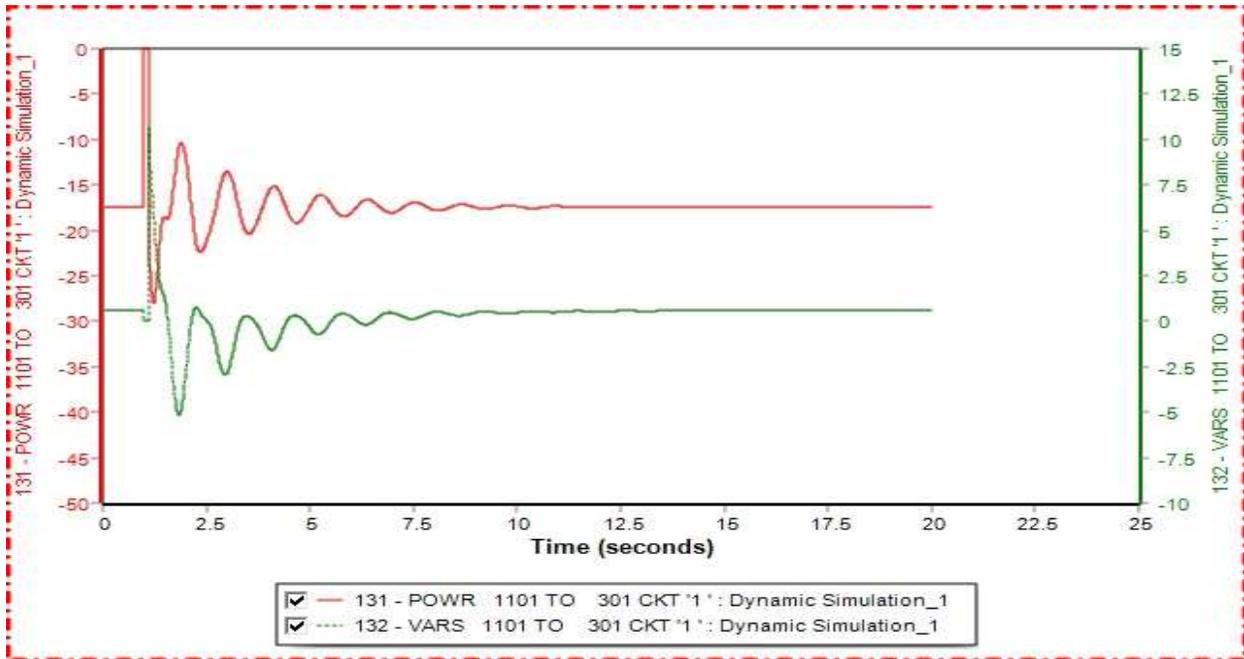


Fig 4.5.15: Active and Reactive power at Malakand III and Mardan II

Oscillations in the rotor angle of generator at bus 1101. Fault is applied at $t = 1.1s$ and cleared at $t = 1.16s$ (8-Cycles standard)

Discrepancy in voltages magnitude causes Var transmission between two points and similarly active power transmission takes place due to differences in phase angle.

Phase angle difference regulates active power and regulation of Var is underneath voltages magnitude difference. The sufficient reservation and correct control of the network Var resources play a vital role in preventing voltage instability. Voltage instability can be averted by regulating Network Var resources sufficiently. [7]

At both ends of the transmission lines there are rotating machines having inertia due to considerable perturbations there's increase in phase angles and system which was operating in a steady state condition becomes unstable. The design of such a line to transmit larger power than before fault at maximum angular swing is utmost important which may consume more reactive

power by the line current because of increased phase angles. Therefore, reactive power generation is a must for this.

Generation of reactive power is utmost important for securing transient stable state. It's possible if the line is operated adequately below its surge impedance power prior to perturbations or Transiently Var addition at the point of time when phase angle of line will be exceptionally increased.

If the mechanism for fast voltage control through the line is not sufficient specially during severe “Back Swing” which is a transient phase when the power transmitted is lower than pre-fault level and secondly when the units loss synchronism or during a load rejection condition ,both solution lead to dangerous over voltages. [7] But the Active and reactive power plots for Mardan II and relevant Network show no load rejection situation which may lead to loss of stability.

4.5.16 Electrical power generated and Reactive power at Chakdara New and Chakdara 220 KV grid:

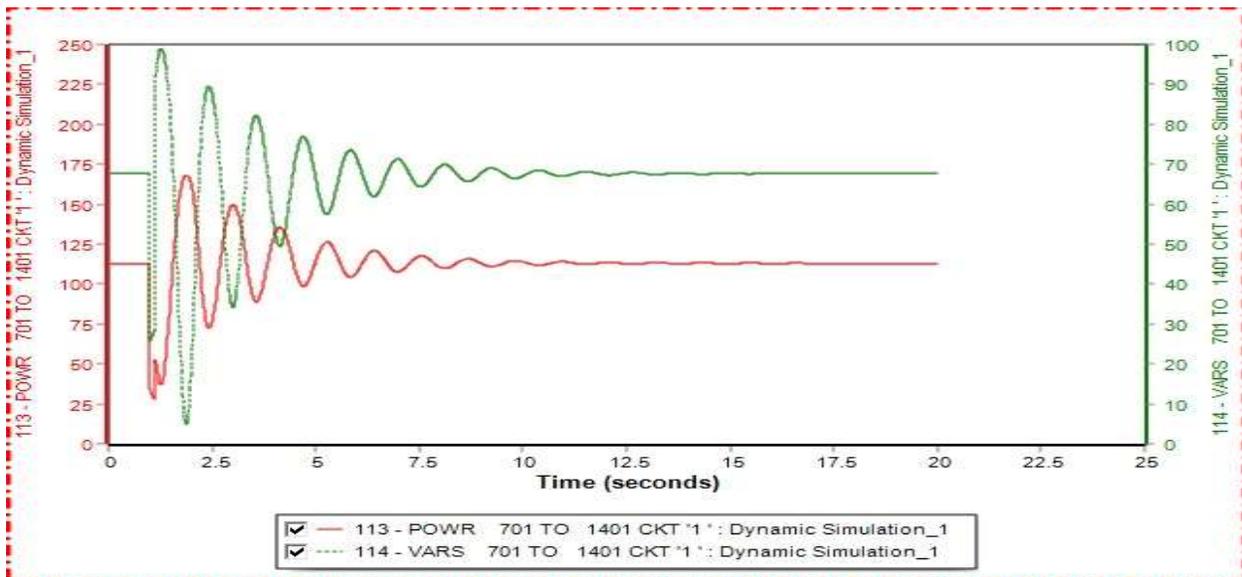


Fig 4.5.16: Active and Reactive power at Chakdara New and Chakdara 220 KV bus

4.5.17 Electrical power generated and Reactive power at Mardan II to Mardan:

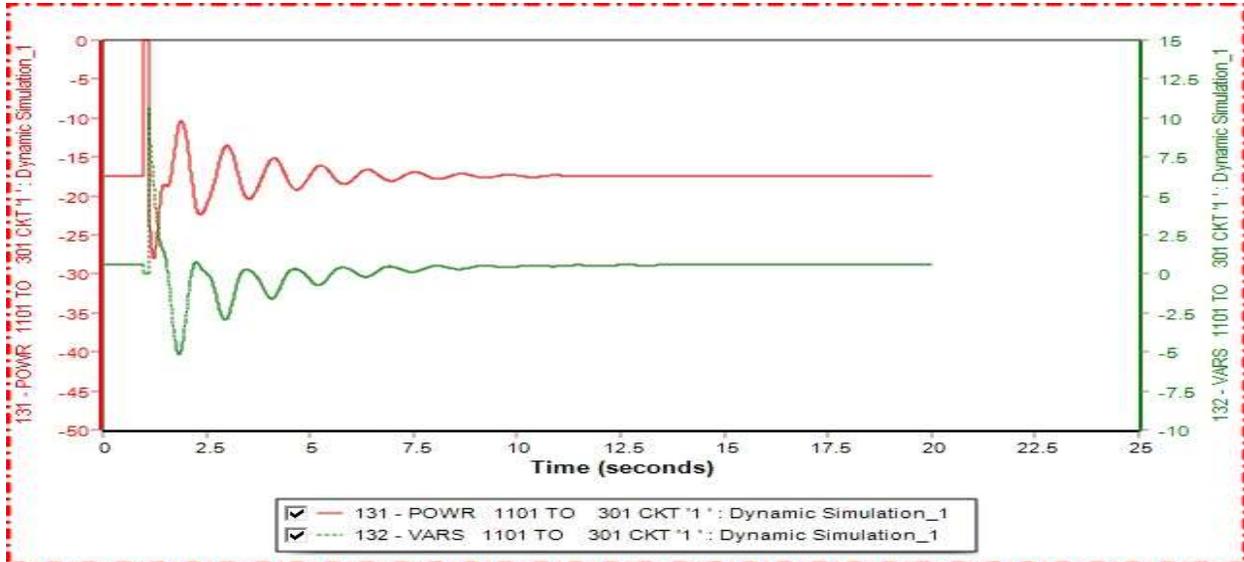


Fig 4.5.17: Electrical power generated and Reactive power at Mardan II to Mardan

4.5.18 Electrical power generated and Reactive power at Mardan II to Shergarh:

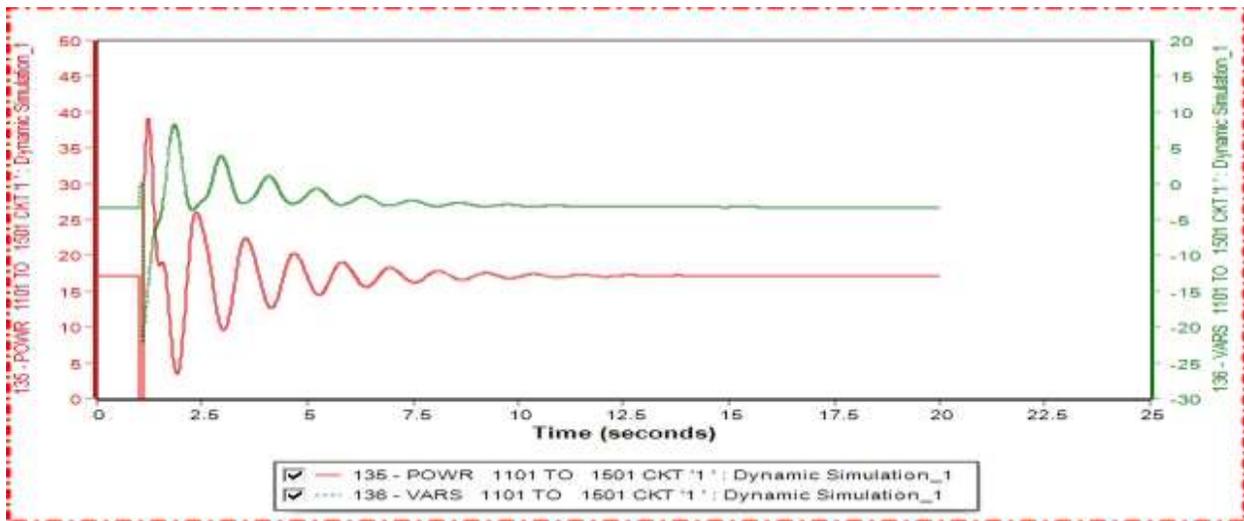


Fig 4.5.18: Active and Reactive power at Mardan II to Shergarh

Future Scope:

In Electrical Power System for a thorough Protection some implementation tools are required for intelligent control. Perturbation in the System are well detected with PSS®E. Dynamic Simulation helps in providing algorithmic solution for transient faults that have huge effect on Power System.

In this report for SLD and most austere 3- ϕ faults algorithmic solution has been provided for rapid dig up and protection of Power System under such phenomena. Due to capacity of the Network for more power interconnection, wind power and HVDC interconnection is also possible with the existing Power Network. The study presented in this report provide a pathway for the detection of unbalanced faults with great efficiency in a steady circumstances of calculation.

References

[1]. "Power system stability and control" Vol. 7. 1994: McGraw-hill New York. Kundur, P.s.N.J. Balu, and M.G Lauby

- [2] “Principal components analysis”. Dunteman, G.H., 1989: Sage.
- [3]. “An introduction to wavelets. Computational Science & Engineering” IEEE Graps, A.,1995.
2(2): p. 50-61.
- [4] “Advanced Electric power Network analysis “Booming Zhang,Zheng Yan.
- [5] “Embedded Generation” Nikolas Genkins, 2000
- [6] “Power System Dynamics and Stability”, Richard G. Farmer ,Arizona State University
- [7] “Electrical Engineer's Reference Book”Sixteenth edition M. A. Laugh to CEng., FIEE,D. J. Warne CEng., FIEE
- [8] “Power system dynamics stability and control” K.R.Padiyar
- [9] “Modern Power system analysis”,D.P.Kothari
- [10] “National Power System Expansion Plan 2011 – 2030” NTDC
- [11] “Hydro and Wind Power Integration: A Case Study of Dargai Station in Pakistan”, July 6, 2012
- [12] “Planning and analysis of a grid connection for future hydro power plants”, Claus Leth-Bak, 2012
- [13] “Modelling and Analysis of a CSP Plant Technology for Small Power Networks -Technical and Financial Evaluation”, Innocent E. Davidson, Nicky K. Mbaimbai, Conference paper November, 2014.