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Graphical User Interface Model of Load Flow Studies by Simulation

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***Abstract*—Load flow is primary consideration in many of the power system problems. The paper discusses the application of Graphical User Interface to load flow study with the use of Gauss-Seidel method for calculation. The Graphical User Interface gives understanding approach to the load flow. The result verification is executed with 3 bus system.**

***Index Terms*—Graphical User Interface, Load Flow Study, Gauss-Seidel method**

I. INTRODUCTION

Load flow study is one of the important aspect in power system analysis. Load flow study is also known as power flow study as mostly the powers are given rather than currents [1]. Steady state operation is determined by the load flow studies. Load flow is a first step in many power system related issues. The load flow study includes the computation of voltage, current, real power and reactive power flows with respect to loading conditions. This concept is depending upon the study of nature of power flow when one of the lines is under maintenance or out of service without exceeding their loading. With this analysis, need of any additional generation or capacitive VARS is evaluated [2].

The system is nonlinear as power flow through load impedance varies with square of voltage. In order to solve the non linear equations, following iterative methods are used:

1. Gauss-Seidel method
2. Newton-Raphson method
3. Decoupled method
4. Fast decoupled method

These methods are having advantages and disadvantage. The apparent power is given by,

$$S_i = P_i + jQ_i = V_i I_i^* \tag{1}$$

By solving the Equation 1 with the active power (Pi) and reactive power (Qi), the flow equations can be given by,

$$P_i = \sum_{j=1}^{n} V_i V_j Y_{ij} \cos(\theta_{ij} + \delta_j - \delta_i) \tag{2}$$

$$Q_i = -\sum_{j=1}^{n} V_i V_j Y_{ij} \sin(\theta_{ij} + \delta_j - \delta_i) \tag{3}$$

Where,

Pi= Active power at bus i
Qi= Reactive power at bus i
Yij= Magnitude of admittance matrix
Ɵij= Angle of admittance matrix
δi, δj= Angle of sending end and receiving end voltage

The Equations 2 and 3 are called as static load flow equations which contain four unknowns as voltage (|V|), Power angle (δ), and Active power (P) and Reactive power (Q) [6]. We have only two equations to determine these unknowns. Hence at least two values must be specified to solve these equations. Depending upon the specified values, there are three types of buses known as SLACK bus, PV bus and PQ bus.

In SLACK bus, real and reactive power is not known prior to the solution of the problem. Hence, the specific amount of real and reactive power is injected at the bus after obtaining the solution [7]. Generally SLACK bus is considered as number 1 and is also referred as reference bus. The PV bus is also called as generator bus whereas the PQ bus is referred as load bus. [3]

TABLE I. CLASSIFICATION OF BUSES

Bus Type	Specified Quantity	Unknown Quantity
SLACK BUS	Voltage (|V|), Power angle (δ)	Active Power (P), Reactive Power (Q)
PQ BUS	Active Power (P), Reactive Power (Q)	Voltage (|V|), Power angle (δ)
PV BUS	Active Power (P), Voltage (|V|)	Power angle (δ), Reactive Power (Q)

Table I shows the classification of buses along with its specified quantities and unknown quantities.

The **G**raphical **U**ser **I**nterface (GUI) of load flow is developed in Simulation software using Gauss-Seidel method. The work gives better understanding due to user interface. The paper is divided in five sections. Section I gives the introduction of load flow. Section II contains the application of Gauss-Seidel method in load flow studies whereas Section III describes the basic terms in preparing GUI. Section IV highlights the example and the results and Section V presents the conclusions of the work. The work is executed for maximum 6 bus system and can further be extended.

II. APPLICATION OF GAUSS-SEIDEL METHOD IN LOAD FLOW STUDIES

In order to apply the Gauss-Seidel method to load flow studies, two cases are considered. The solution obtained from this method has to be updated until it converges. Considering 'n' number of buses in the system, the cases can be considered as follows:

Case 1: Consider bus number 1 as SLACK bus and remaining (n-1) buses are PQ buses. Table II shows the defined quantities.

Case 2: Consider bus 1 as SLACK bus, (m-1) number of PQ buses where m is a bus number in between 1 to n and (n-m) number of buses as PV buses.

TABLE II. QUANTITIES DEFINED IN CASE 1

Bus Number	**Bus Type**	**Known Quantities**	**Unknown Quantities**
1	SLACK	|V1|, δ1	P1, Q1
2	PQ	P2, Q2	|V2|, δ2
3	PQ	P3, Q3	|V3|, δ3
n	PQ	Pn, Qn	|Vn|, δn

Fig.1 shows typical bus in the system which contains P_{Gi}, Q_{Gi} as the real and reactive powers at the generator. P_{Gi}, Q_{Gi} are the real and reactive power at the load side. V_i is the voltage at i^{th} bus. The Y-bus matrix formation is necessary prior to solving the power flow equations. This matrix is of the order (n*n) where 'n' is the number of buses in the system. Each matrix element is depends on number of transmission lines connected to the bus. The current injected into the bus is given by,

$$I_i = \sum_{k=1}^{n} Y_{ik} V_k \qquad (4)$$

Where,
Y_{ik}= Y- bus matrix element connecting to bus i, k.
V_k = voltage at k^{th} bus

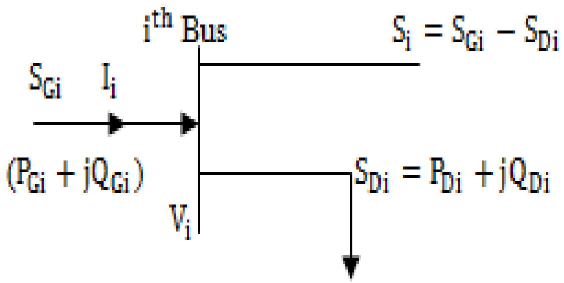

Fig. 1 Typical bus in system [1]

By substituting equation (4) in equation (1) and solving further, we get the voltage at the i^{th} bus as,

$$V_i = \frac{1}{Y_{ii}}\left[\frac{P_i - jQ_i}{V_i^*} - \sum_{\substack{k=1,\\ k\neq i}}^{n} Y_{ik}V_k\right] \qquad (5)$$

Where,
Y_{ii}= Y- bus matrix element at i^{th} bus
V_i^* = Initial voltage at i^{th} bus

The generalized equation of voltage can be written as shown in Equation 6,

$$V_i^{r+1} = \frac{1}{Y_{ii}}\left[\frac{P_i - jQ_i}{(V_i^r)^*} - \sum_{k=1}^{i-1} Y_{ik}V_i^{r+1} - \sum_{k=i+1}^{n} Y_{ik}V_i^r\right] \qquad (6)$$

In the Equation 6, i^{th} bus is not included to calculate the voltage. To increase the rate of convergence, acceleration factor (α) is included in voltage equation [8]. The final equation of voltage along with acceleration factor is mentioned in equation (7).

$$V_i^{r+1}(accelerated) = V_i^r + \alpha(V_i^{r+1} - V_i^r) \qquad (7)$$

Where,
V_i^{r+1}= Value of voltage of current iteration
V_i^r= Value of voltage of previous iteration
α = acceleration factor (generally value taken as 1.6 or 1.7)

Considering Case 2, where all the three types of buses are present and the Table III shows the given quantities in case 2.

Table III. Quantities given in Case 2

Bus Type	Bus Number	Known Quantities	Unknown Quantities
SLACK Bus	1	$\|V1\|, \delta 1$	P1, Q1
PQ Bus	2	P2, Q2	$\|V2\|, \delta 2$
	3	P3, Q3	$\|V3\|, \delta 3$
	⋮	⋮	⋮
	m	P_m, Q_m	$\|V_m\|, \delta_m$
PV Bus	m+1	$P_{m+1}, \|V_{m+1}\|$	Q_{m+1}, δ_{m+1}
	⋮	⋮	⋮
	n	P_n, Q_n	Q_n, δ_n

With the available data the reactive power Q can be calculated as given in Equation 8

$$Q_i = -Img\left[V_i^* \sum_{k=1}^{n} V_k Y_{ik}\right] \qquad (8)$$

This Q_i will give the reactive power at i^{th} bus. Generalized equation of reactive power is given in Equation 9. In this equation sum is splinted at the point where power have to be calculated.

$$Q_i^{r+1} = -Img\left[V_i^{r*}\left(\sum_{k=1}^{i-1} V_i^{r+1} Y_{ik} + \sum_{k=i}^{n} V_k^r Y_{ik}\right)\right] \qquad (9)$$

Once Q_i is obtained, power angle has to be calculated with the use of equation (4). Limits given on Q_i will be considered during calculating Q_i. If Q_i exceed the given limit then corresponding bus is converted in to PQ bus with Q_i is set either at maximum or minimum value and unknowns will be calculated [2].

III. GUI USING SIMULATION AND ITS APPLICATION TO LOAD FLOW STUDIES

In order to simplify the use of simulation programs, GUI provides a pictorial interface to the programs [4]. It provides a insightful appearance with controls such as pushbuttons, edit boxes, list boxes, sliders, menus, etc. At every stage of a program where the user defined inputs are needed, GUI works in explicable and predictable manner thus simplifying the situation. This helps the user in focusing on the principle of application rather than the technicalities involved.

GUI programs are identified as 'event driven programs' since an input that is events are provided by mouse clicks. Simulation tool GUI consists of three essential elements. They are components, containers and call backs [9].

A. Components: Every constituent of Simulation tool GUI is a graphical component. Components are further classified as graphical controls, static elements, menus, toolbars and axes. Graphical controls consist of pushbuttons, toggle buttons, edit boxes, lists, sliders, etc. While static elements consist of text boxes. Functions uicontrol is used to create graphical controls and static elements. Whereas functions uimenu and uicontextmenu are used to create menu. Physical properties of components such as background colour, foreground colour, font size, font colour, etc. can be altered depending upon the choice of user.

B. Containers: Container is window on the computer screen within which components of GUI are arranged. Figure is one of the most common containers.

C. Callbacks: The Simulator tool code which must be executed in response to the events are known as callbacks. [5]

Various components of GUI are described as follows:

1. Edit boxes: Edit box allows the user to enter text string. If max property of edit box is set to a value greater than 1, multiple text strings can be entered as shown in Fig. 2.

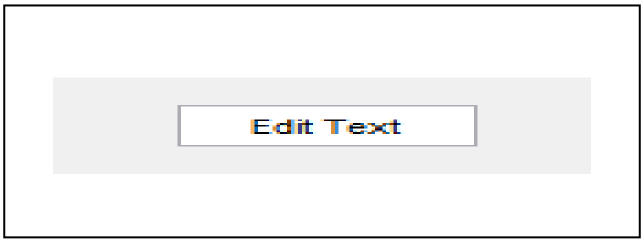

Fig. 2 Edit Box in GUI

2. Push buttons: Whenever the user clicks on a push button, specified action is triggered. Intended task is programmed in the callback section of pushbutton as shown in Fig. 3.

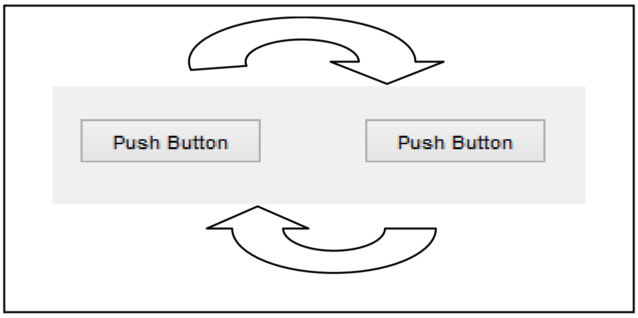

Fig. 3 Push button in GUI

3. Radio button: It is a type of toggle button. It has two switching states ON and OFF. Whenever radio button is clicked for the first time, a dot appears in the centre of the circle indicating that it is in ON state as shown in Fig. 4.

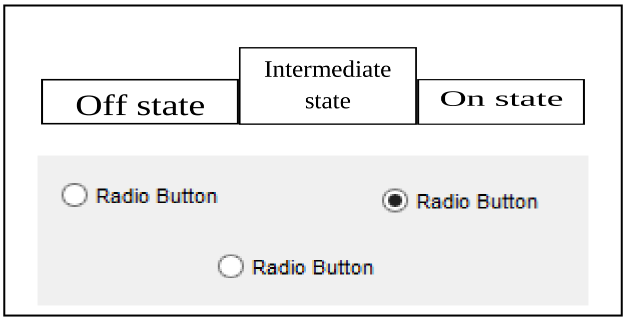

Fig. 4 Radio button in GUI

4. Popup menus: Whenever a popup menu is clicked, a list of available options appears and the user is expected to select one among the available options as shown in Fig. 5.

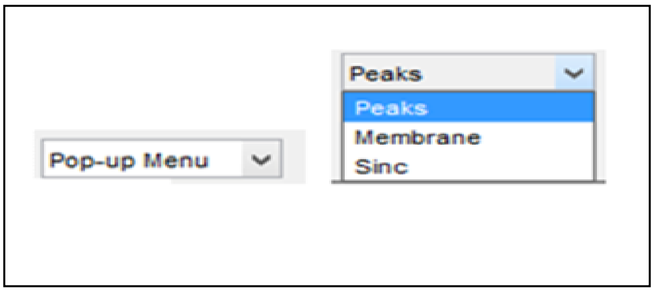

Fig. 5 Pop-up button in GUI

Using these graphical controls, GUI model is used to make the load flow studies of a power system more users friendly.

Computational steps of the load flow program are shown in Fig. 6.

IV. TYPICAL EXAMPLE AND RESULT

Fig. 7 shows single line diagram of three bus system with generators at buses 1 and 3. The magnitude of voltage at bus 1 is adjusted to 1.05 pu. Voltage magnitude at bus 3 is fixed at 1.04 pu. with a real power generation of 200 MW. A load consisting of 400 MW and 250 MVAR is taken from bus 2. Line impedances are marked in pu. on a 100 MVA base and the line charging susceptances are neglected. The power flow solution is obtained by Gauss-Seidel method. [1]

This data is feed in the GUI which is shown in Fig 8. During feeding of data all impedances has to be converted into corresponding admittances and the power are converted to per unit system. The results are shown in Fig. 9. The results are compared with results obtained by theoretical calculations.

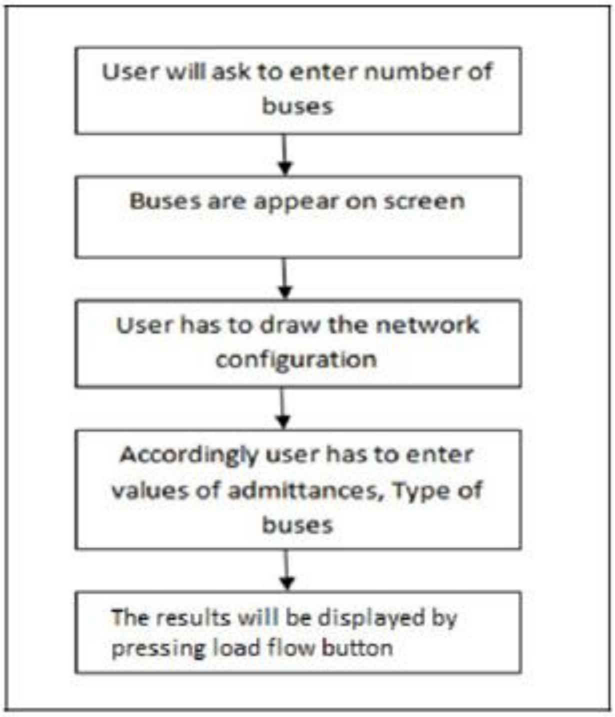

Fig. 6 Flowchart for solving load flow problems

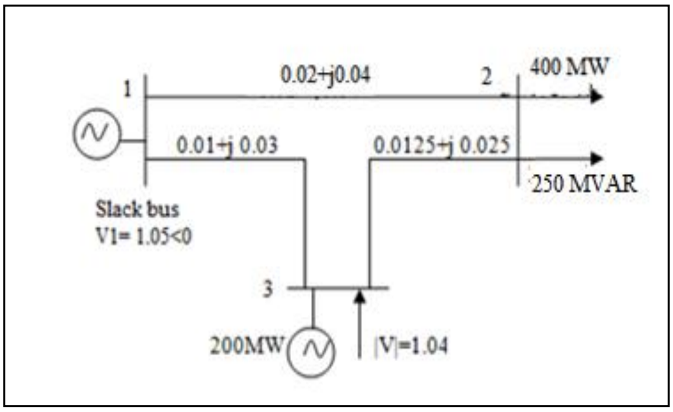

Fig.7 Single line diagram of three bus system

V. CONCLUSIONS

The GUI model make easy understanding of load flow study. The computational time required is less than the calculations done by hand. The user is required to enter the network along with sufficient data. The other parameters are calculated by program.

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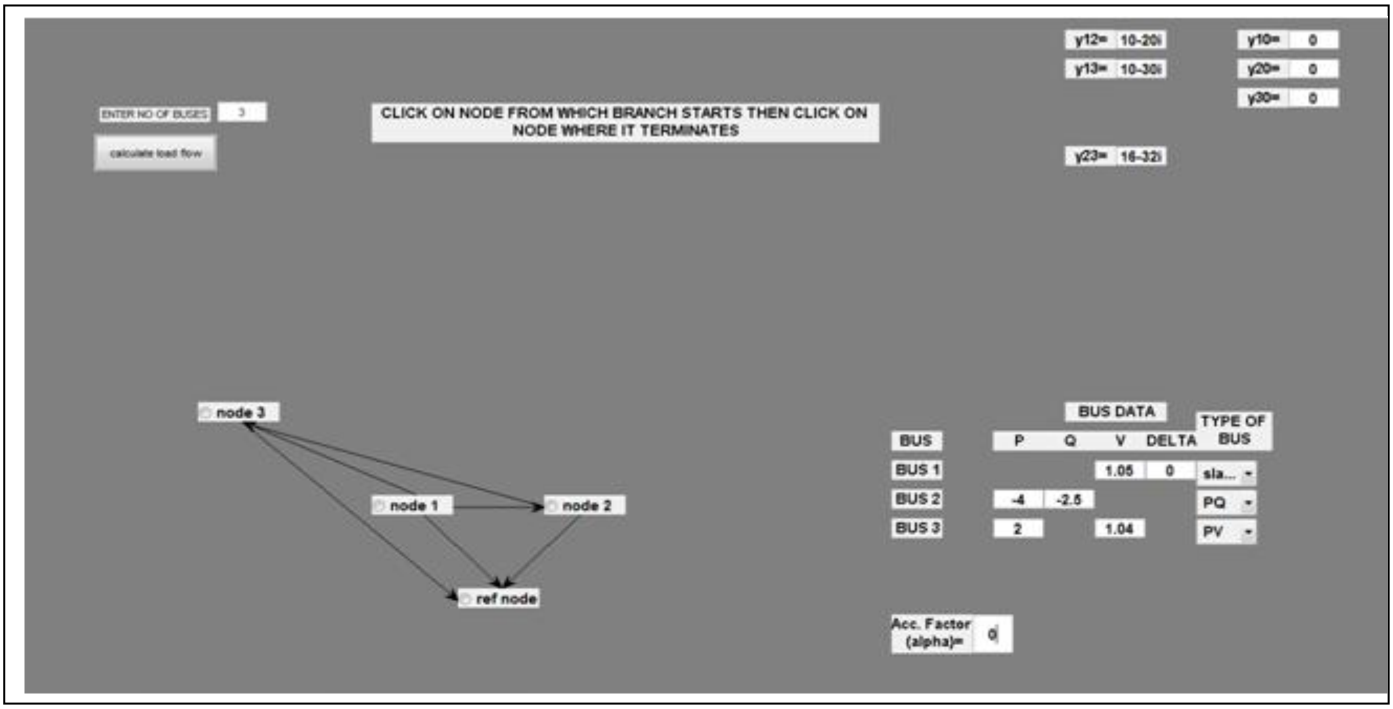

Fig. 8 Data entry in GUI model

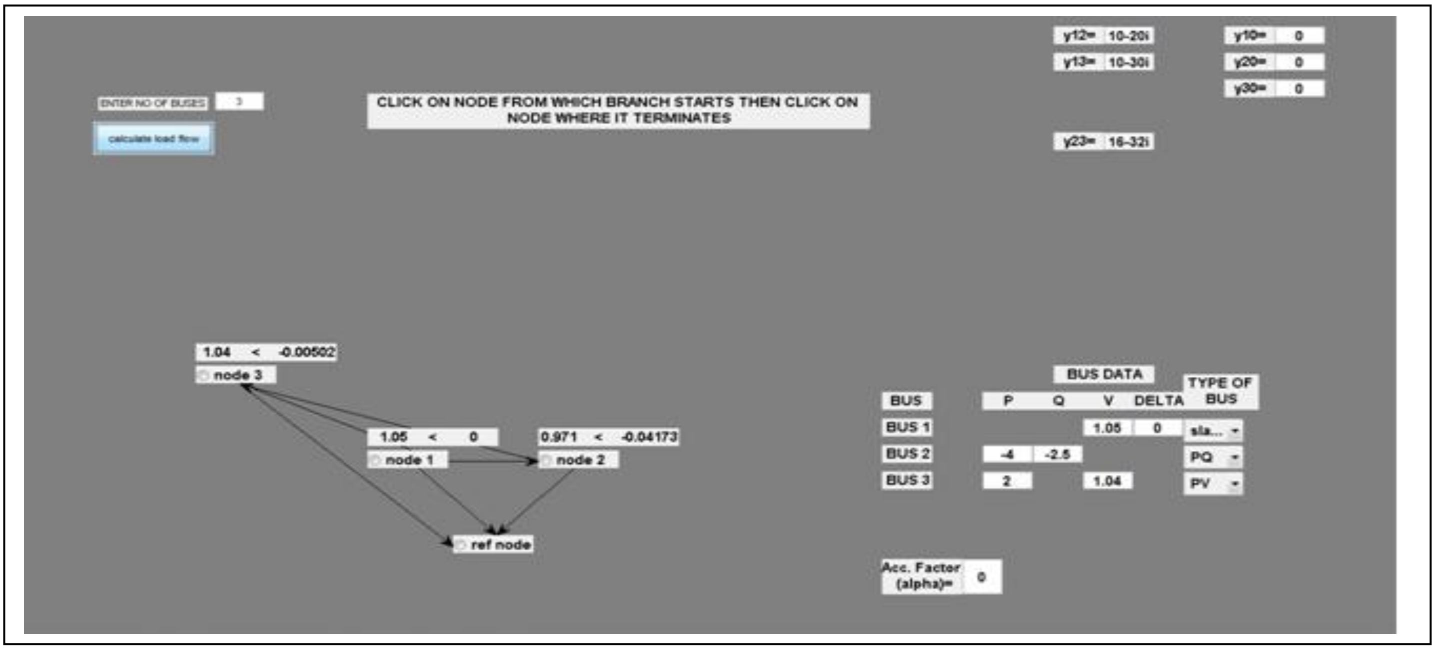

Fig. 9 Results obtained in GUI model

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