Power Flow Analysis of IEEE 33 Bus Radial Distribution Systems using DigSilent

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Abstract- This paper presents a method to identify least voltage profile and optimally place the capacitor in the distribution systems. The aim of this paper is to design locations of capacitor using DigSilent software optimally. The method of obtaining low voltage profile of a particular bus is complex in nature. The calculations are longer and time consuming for getting a converged solution. The DigSilent software used to perform load flow and short circuit of IEEE 33 bus radial distribution system. The developed power system network in the DigSilent software with least voltage profile bus and incorporate optimal capacitor location.

Keywords – DigSilent software, optimal capacitor location, voltage profile, Newton-Raphson method

I. Introduction

The power distribution system is complex in nature as the consumers play a vital role. Power quality in distribution system is important aspect for the consumers at different load conditions. The criteria of power quality parameters are maintaining constant voltage, maintaining constant frequency and distortion less waveform. The constant voltage profile should be within the limit gives good reliability to the consumers. The reconfiguration of feeder is important in the distribution system for maintaining good reliability and feeder topology changed to minimize the losses. This feeder changing topology obtained using optimization algorithm [1]. The reactive power is important concern as the voltage varies widely when reactive power changes. The reactive power of switched capacitors, tap changing transformers are regulated automatically [2]. In radial distribution systems, faultfinding is an important aspect, and the sensitivity analysis established in [5-6]. In distribution system, new loads cannot add directly because it leads to poor power quality. This analysis done with suitable load flow solution and addition of new load investigated using DigSilent software [7]. The load flow analysis is performed in simple calculations using algebraic expression instead of complex Jacobian matrices for solving many Indian radial distribution systems [10]. In radial distribution, load flow analysis cannot be solved as power transmission system. The algorithm needs to modify for the suitability conditions and R/X ratio values are more compared to transmission systems. The one of the prominent method is newton method, which envisages the performance of distribution system. However, Newton method has drawbacks of iterations are more solving the problem compared to Newton Raphson method [12]. In the distribution system, the installation of voltage regulators incorporated by calculating the losses on each bus. The bus with highest loss is selected, suitable regulators are added, and using PSO optimization algorithm suitable tap setting is selected. In this method cost of installing and maintaining of voltage regulators are high instead of capacitors [15]. Load flow analysis has several methods for solving radial distribution systems they are Newton method, Newton Raphson method, decoupled method, fast-decoupled method, object oriented programming method and optimization algorithm [16]. The power flow analysis of distribution system simulated by matpower open source software based on matlab package. The DigSilent software has many features compared to the matpower software [17]. The rest of the paper organized as follows. Newton Raphson algorithm of solving IEEE 33 bus radial bus system explained in section II. Diagnostic results presented in section III. Concluding remarks are given in section IV.

II. NEWTON RAPHSON METHOD OF IEEE 33 BUS RADIAL DISTRIBUTION SYSTEM

2.1 Newton-Raphson method –

The basic aim of load flow study is to find the voltage magnitude and phase angle of each bus. From these two output data, all other parameters like active power, reactive power, apparent power, power losses, voltage drop and many other electrical measureable quantities can be obtained. The main advantage of this method has good convergence characteristics and hence the solution is reached quickly. The real time power system has many numbers of buses, distribution line, loads with linear and non-linear type. Hence, for the large distribution network other classical method fails to yield the result. The mathematical equations are framed such that when new loads are added or new distribution line is added the calculations is more adaptable compared to other techniques. There are some drawbacks of this method, the calculation are more and requires more time for a particular iteration. This improved by using computer simulation. The Jacobian elements occupy more space hence the speed of solution is slower. This enhanced by using spare matrix and gauss elimination method for faster and less storage requirements. The IEEE 33 bus radial distribution system is as shown in figure1.

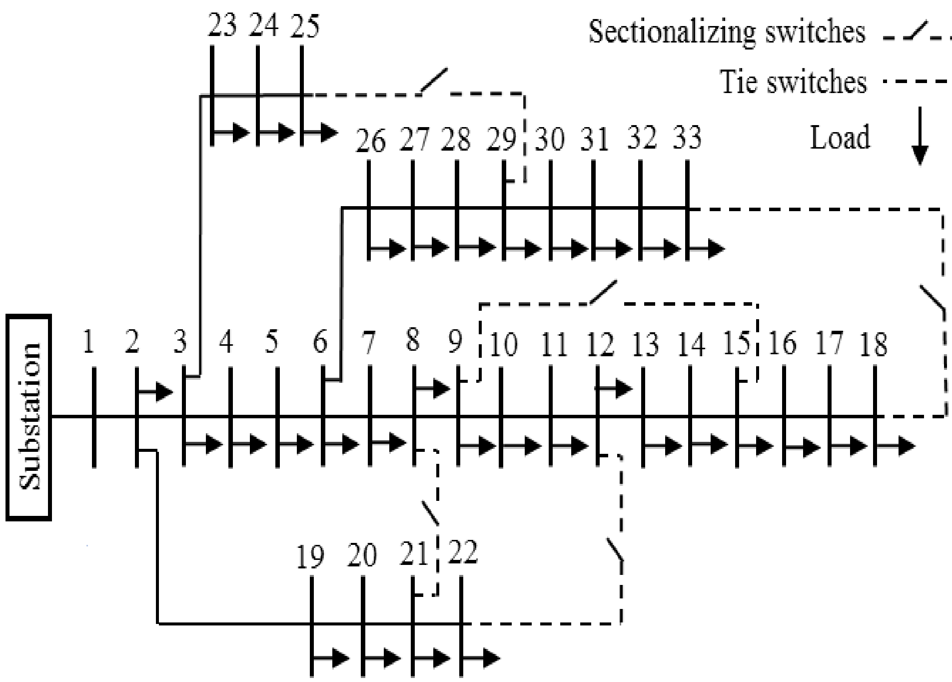


Figure 1. IEEE 33 bus single line diagram

In power distribution, system topology model is either radial or ring network. The reliability criteria requirement is prime importance and thus the calculation is difficult. The R/X ratio values in high voltage transmission system are comparatively lesser than low voltage distribution systems. Distributed generation for radial type is taken for the analysis. The loads are not static type but it has rectifier, scada and many other dynamic loads [20]. It is understood that, classical algorithm unable to solve the distribution problems. The dynamic Newton-Raphson (NR) solves the distribution problem with good accuracy. The NR method Jacobian matrix is as shown in equation 1.

$$\begin{bmatrix} \Delta P_2^{(k)} \\ \vdots \\ \Delta P_n^{(k)} \\ \hline \Delta Q_2^{(k)} \\ \vdots \\ \Delta Q_n^{(k)} \end{bmatrix} = \left[\begin{array}{c|c} \begin{pmatrix} \frac{\partial P_2^{(k)}}{\partial \delta_2^{(k)}} & \cdots & \frac{\partial P_2^{(k)}}{\partial \delta_n^{(k)}} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n^{(k)}}{\partial \delta_2^{(k)}} & \cdots & \frac{\partial P_n^{(k)}}{\partial \delta_n^{(k)}} \end{pmatrix} & \begin{pmatrix} \frac{\partial P_2^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial P_2^{(k)}}{\partial |V_n|} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial P_n^{(k)}}{\partial |V_n|} \end{pmatrix} \\ \hline \begin{pmatrix} \frac{\partial Q_2^{(k)}}{\partial \delta_2^{(k)}} & \cdots & \frac{\partial Q_n^{(k)}}{\partial \delta_2^{(k)}} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n^{(k)}}{\partial \delta_2^{(k)}} & \cdots & \frac{\partial Q_n^{(k)}}{\partial \delta_n^{(k)}} \end{pmatrix} & \begin{pmatrix} \frac{\partial Q_2^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial Q_2^{(k)}}{\partial |V_n|} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial Q_n^{(k)}}{\partial |V_n|} \end{pmatrix} \end{array}\right] \begin{bmatrix} \Delta \delta_2^{(k)} \\ \vdots \\ \Delta \delta_n^{(k)} \\ \hline \Delta \left|V_2^{(k)}\right| \\ \vdots \\ \Delta \left|V_n^{(k)}\right| \end{bmatrix} \tag{1}$$

$$\begin{bmatrix} \Delta P \\ \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ \\ J_3 & J_{41} \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \\ \Delta|V| \end{bmatrix} \tag{2}$$

$$\frac{\partial P_p}{\partial \delta_p} = \sum_{j=1} |V_p||V_j||Y_{pj}|\cos(\theta_{pj} - \delta_p + \delta_j) \tag{3}$$

$$\frac{\partial P_p}{\partial \delta_j} = \sum_{j=1} |V_p||V_j||Y_{pj}|\cos(\theta_{pj} - \delta_p + \delta_j) \tag{4}$$

The equation 2 specifies the Jacobian matrix in general form. The diagonal and off diagonal elements of J_1 is shown in equation 3 and 4. The values of ΔP and ΔQ obtained by using the equation 4

$$\Delta P_i^k = P_i^{sp} - P_i^k \qquad \Delta Q_i^k = Q_i^{sp} - Q_i^k \tag{5}$$

From the equation 2 Δδ and ΔV is found out by inversing the matrix. The values of angle and voltage updated iteration until it converges.

$$\delta_i^{(k+1)} = \delta_i^{(k)} + \Delta\delta_i^{(k)} \qquad \left|V_i^{(k+1)}\right| = \left|V_i^{(k)}\right| + \left|\Delta V_i^{(k)}\right| \tag{6}$$

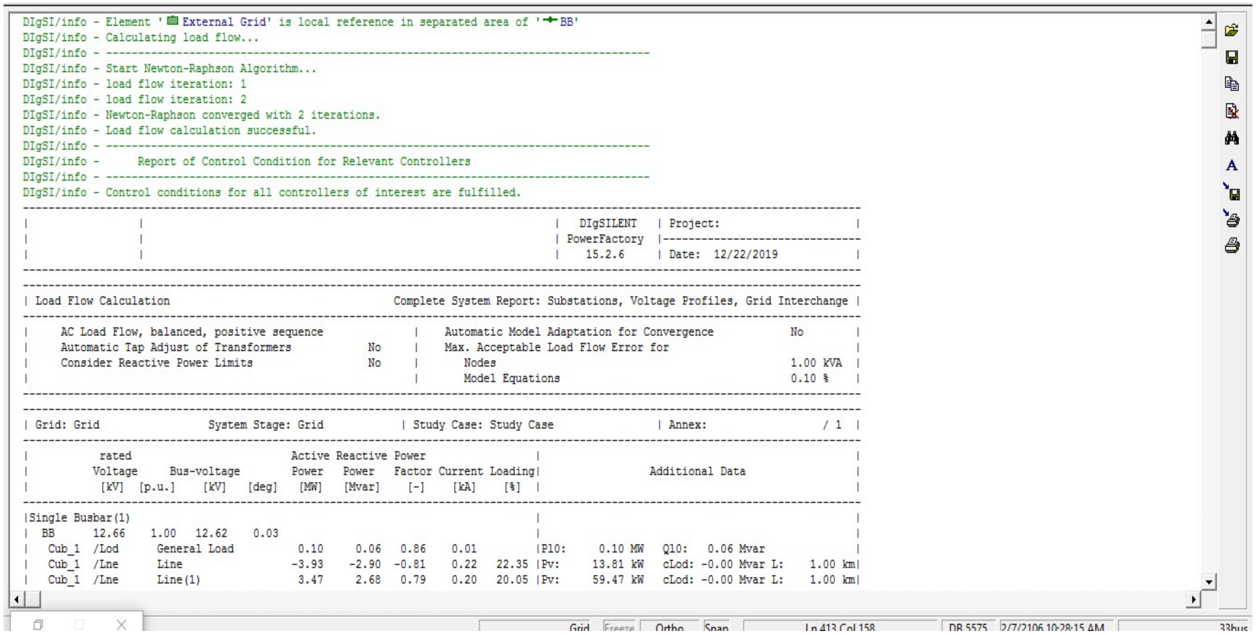
The result is converged when the value reached the tolerance factor and solution obtained.

2.2. DigSILENT Powerfactory Software –

The DigSilent power factory software deals with simulation of generation, transmission and distribution systems in real time applications [19]. This software is more flexibility and useful in testing with highly automated systems. There are many features available in the software they are load flow and short circuit analysis of transmission and distribution systems, short circuit study, reliability study, transient stability study, B coefficient analysis and many more. The network diagram shows pictorial representation of real time scenario and simulated for accurate study. The new version of DigSilent power factory software has updated features of renewable energy system, grid integration, protection systems and distributed generation.

III. Experiment and Result

In DigSilent, power factory software the IEEE 33 bus radial bus system drawn in network editor for showing the diagnostic result. The components of distribution system drawn in the software network editor, they are transformers, distribution line, loads, capacitor for optimal placement and bus bar. After drawing the power system network, all the given data entered and simulated. The convergence in achieved in two iterations, which depicted in figure 2.



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DIgSI/info - Element ' External Grid' is local reference in separated area of ' BB'
DIgSI/info - Calculating load flow...
DIgSI/info - ------------------------------------------------------------------------------------
DIgSI/info - Start Newton-Raphson Algorithm...
DIgSI/info - load flow iteration: 1
DIgSI/info - load flow iteration: 2
DIgSI/info - Newton-Raphson converged with 2 iterations.
DIgSI/info - Load flow calculation successful.
DIgSI/info - ------------------------------------------------------------------------------------
DIgSI/info -      Report of Control Condition for Relevant Controllers
DIgSI/info - ------------------------------------------------------------------------------------
DIgSI/info - Control conditions for all controllers of interest are fulfilled.
------------------------------------------------------------------------------------------------------------------
|              |                                                      |   DIgSILENT   | Project:                  |
|              |                                                      | PowerFactory  |---------------------------
|              |                                                      |    15.2.6     | Date:  12/22/2019         |
------------------------------------------------------------------------------------------------------------------
------------------------------------------------------------------------------------------------------------------
| Load Flow Calculation                        Complete System Report: Substations, Voltage Profiles, Grid Interchange |
------------------------------------------------------------------------------------------------------------------
|    AC Load Flow, balanced, positive sequence           |   Automatic Model Adaptation for Convergence          No      |
|    Automatic Tap Adjust of Transformers           No   |   Max. Acceptable Load Flow Error for                         |
|    Consider Reactive Power Limits                 No   |     Nodes                                         1.00 kVA  |
|                                                        |     Model Equations                               0.10 %    |
------------------------------------------------------------------------------------------------------------------
------------------------------------------------------------------------------------------------------------------
| Grid: Grid               System Stage: Grid           | Study Case: Study Case               | Annex:           / 1  |
------------------------------------------------------------------------------------------------------------------
|         rated                          Active Reactive Power                   |                                      |
|        Voltage     Bus-voltage          Power   Power  Factor Current Loading|              Additional Data         |
|         [kV]  [p.u.]    [kV]   [deg]    [MW]   [Mvar]    [-]    [kA]    [%]  |                                      |
------------------------------------------------------------------------------------------------------------------
|Single Busbar(1)                                                               |                                      |
|  BB       12.66    1.00   12.62    0.03                                       |                                      |
|   Cub_1  /Lod      General Load       0.10     0.06   0.86    0.01           |P10:     0.10 MW   Q10:   0.06 Mvar      |
|   Cub_1  /Lne      Line              -3.93    -2.90  -0.81    0.22    22.35  |Pv:     13.81 kW   cLod: -0.00 Mvar L:    1.00 km|
|   Cub_1  /Lne      Line(1)            3.47     2.68   0.79    0.20    20.05  |Pv:     59.47 kW   cLod: -0.00 Mvar L:    1.00 km|
```

Figure 2. Load flow result with number of iterations

The load flow analysis computed and grphical results depicted in figure 3 using DigSilent, power factory software.

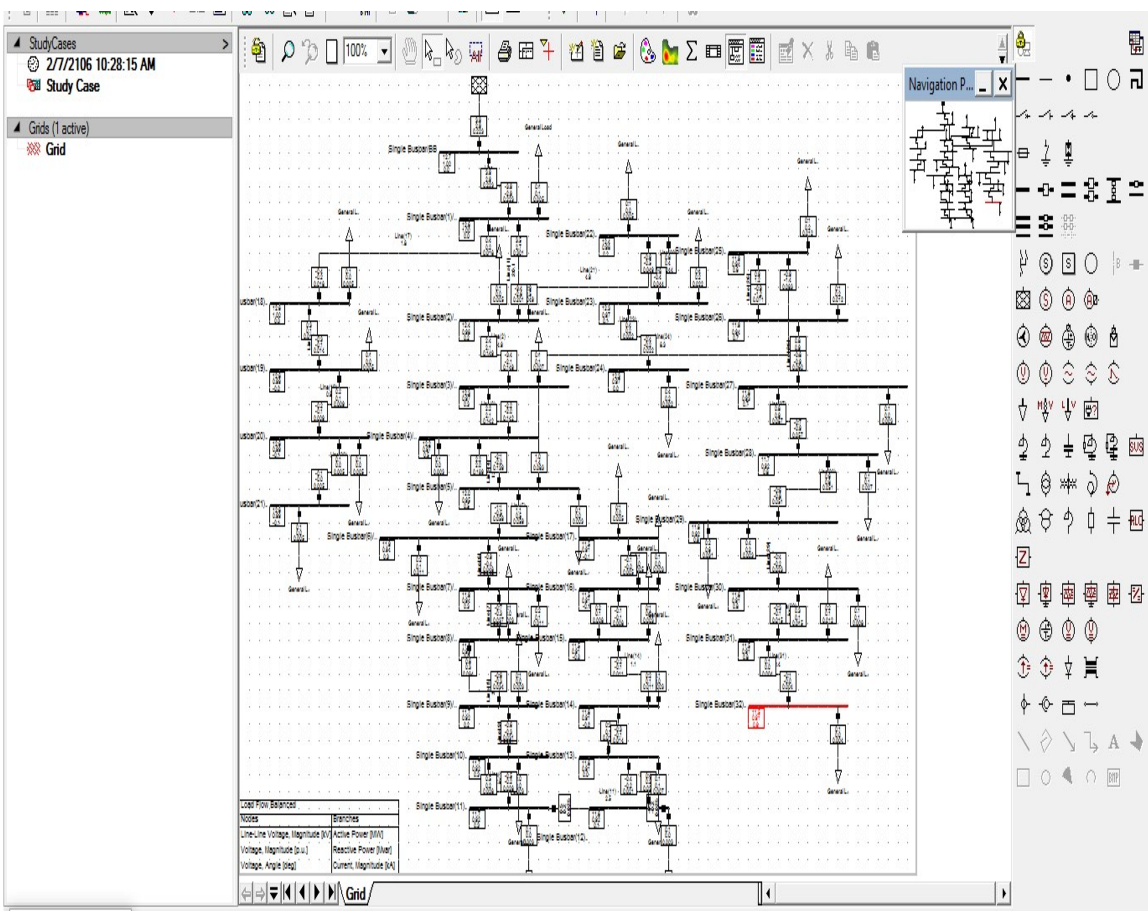
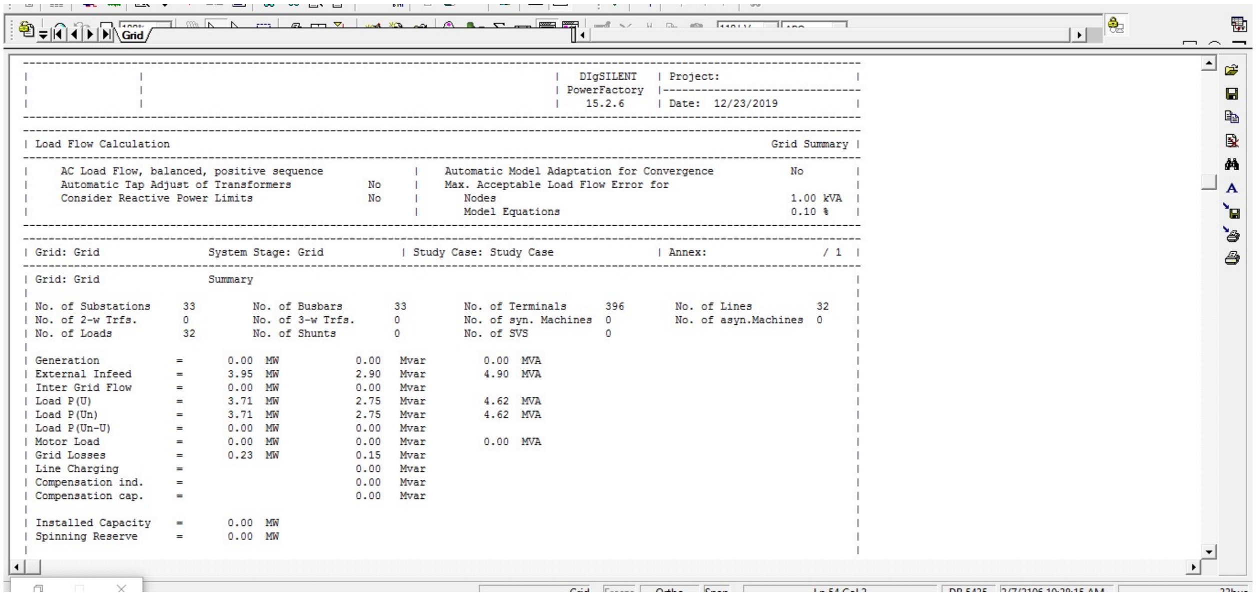


Figure 3. IEEE 33 bus radial system in DigSILENT

The grid summary of IEEE 33 bus radial bus system is displayed in figure 4 with total power distributed in the network.



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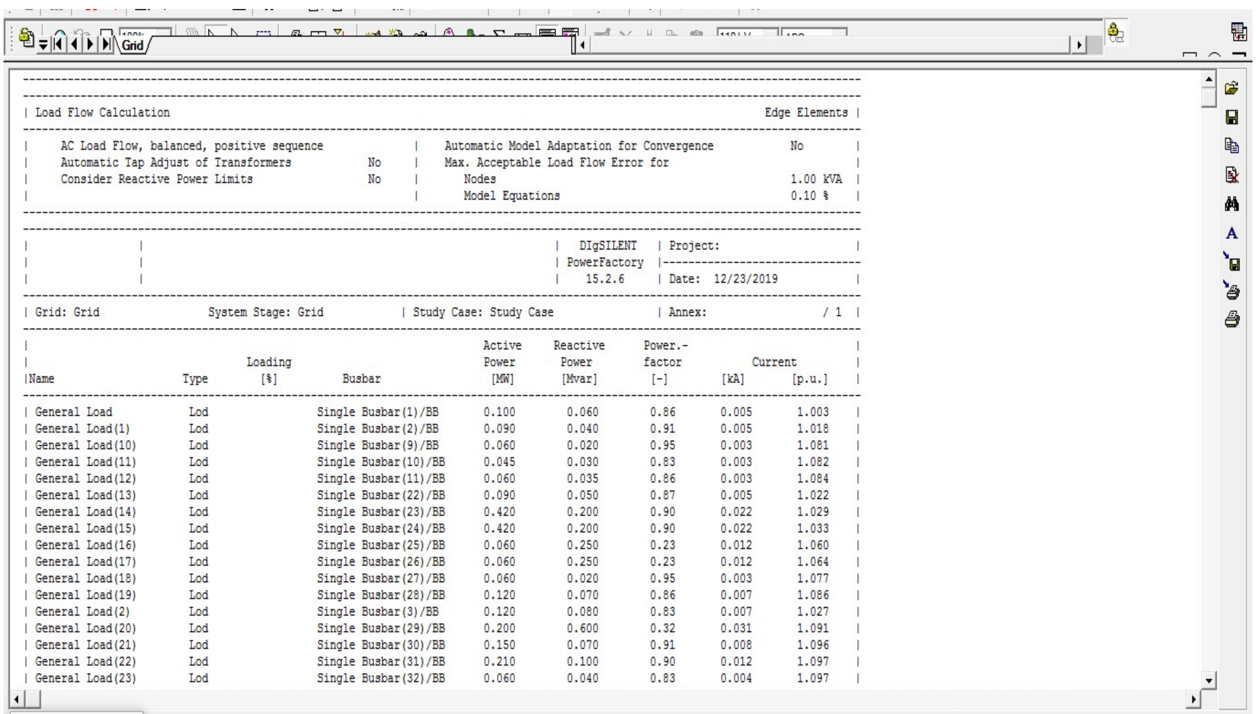
| Load Flow Calculation                                                              Grid Summary |
| AC Load Flow, balanced, positive sequence          | Automatic Model Adaptation for Convergence    No
| Automatic Tap Adjust of Transformers         No    | Max. Acceptable Load Flow Error for
| Consider Reactive Power Limits               No    |   Nodes                                 1.00 kVA
|                                                    |   Model Equations                       0.10 %
| DIgSILENT PowerFactory 15.2.6 | Project: | Date: 12/23/2019
| Grid: Grid          System Stage: Grid      | Study Case: Study Case          | Annex:          / 1 |
| Grid: Grid          Summary
| No. of Substations   33    No. of Busbars   33    No. of Terminals     396    No. of Lines           32
| No. of 2-w Trfs.     0     No. of 3-w Trfs. 0     No. of syn. Machines 0      No. of asyn.Machines   0
| No. of Loads         32    No. of Shunts    0     No. of SVS           0
|
| Generation          =   0.00  MW     0.00  Mvar     0.00  MVA
| External Infeed     =   3.95  MW     2.90  Mvar     4.90  MVA
| Inter Grid Flow     =   0.00  MW     0.00  Mvar
| Load P(U)           =   3.71  MW     2.75  Mvar     4.62  MVA
| Load P(Un)          =   3.71  MW     2.75  Mvar     4.62  MVA
| Load P(Un-U)        =   0.00  MW     0.00  Mvar
| Motor Load          =   0.00  MW     0.00  Mvar     0.00  MVA
| Grid Losses         =   0.23  MW     0.15  Mvar
| Line Charging       =                 0.00  Mvar
| Compensation ind.   =                 0.00  Mvar
| Compensation cap.   =                 0.00  Mvar
|
| Installed Capacity  =   0.00  MW
| Spinning Reserve    =   0.00  MW
```

Figure 4. Grid summary of IEEE 33 bus system

The load profile of IEEE 33 bus radial bus system is displayed in figure 5, showing active power, reactive power, power factor, current both in kilo amperes and in per unit.



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| Load Flow Calculation                                                              Edge Elements |
| AC Load Flow, balanced, positive sequence          | Automatic Model Adaptation for Convergence    No
| Automatic Tap Adjust of Transformers         No    | Max. Acceptable Load Flow Error for
| Consider Reactive Power Limits               No    |   Nodes                                 1.00 kVA
|                                                    |   Model Equations                       0.10 %
| DIgSILENT PowerFactory 15.2.6 | Project: | Date: 12/23/2019
| Grid: Grid          System Stage: Grid      | Study Case: Study Case          | Annex:          / 1 |
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Name	Type	Loading [%]	Busbar	Active Power [MW]	Reactive Power [Mvar]	Power.-factor [-]	Current [kA]	Current [p.u.]
General Load	Lod		Single Busbar(1)/BB	0.100	0.060	0.86	0.005	1.003
General Load(1)	Lod		Single Busbar(2)/BB	0.090	0.040	0.91	0.005	1.018
General Load(10)	Lod		Single Busbar(9)/BB	0.060	0.020	0.95	0.003	1.081
General Load(11)	Lod		Single Busbar(10)/BB	0.045	0.030	0.83	0.003	1.082
General Load(12)	Lod		Single Busbar(11)/BB	0.060	0.035	0.86	0.003	1.084
General Load(13)	Lod		Single Busbar(22)/BB	0.090	0.050	0.87	0.005	1.022
General Load(14)	Lod		Single Busbar(23)/BB	0.420	0.200	0.90	0.022	1.029
General Load(15)	Lod		Single Busbar(24)/BB	0.420	0.200	0.90	0.022	1.033
General Load(16)	Lod		Single Busbar(25)/BB	0.060	0.250	0.23	0.012	1.060
General Load(17)	Lod		Single Busbar(26)/BB	0.060	0.250	0.23	0.012	1.064
General Load(18)	Lod		Single Busbar(27)/BB	0.060	0.020	0.95	0.003	1.077
General Load(19)	Lod		Single Busbar(28)/BB	0.120	0.070	0.86	0.007	1.086
General Load(2)	Lod		Single Busbar(3)/BB	0.120	0.080	0.83	0.007	1.027
General Load(20)	Lod		Single Busbar(29)/BB	0.200	0.600	0.32	0.031	1.091
General Load(21)	Lod		Single Busbar(30)/BB	0.150	0.070	0.91	0.008	1.096
General Load(22)	Lod		Single Busbar(31)/BB	0.210	0.100	0.90	0.012	1.097
General Load(23)	Lod		Single Busbar(32)/BB	0.060	0.040	0.83	0.004	1.097

Figure 5. Load profile of IEEE 33 bus system

The line profile of IEEE 33 bus radial bus system is displayed in figure 6, showing active power, reactive power, power factor, current both in kilo amperes and in per unit.

Name	Type	Loading [%]	Busbar	Active Power [MW]	Reactive Power [Mvar]	Power.-factor [-]	Current [kA]	Current [p.u.]
External Grid	Xnet		Single Busbar/BB	3.947	2.903	0.81	0.223	0.003
Line	Lne	22.35	Single Busbar/BB	3.947	2.903	0.81	0.223	0.223
			Single Busbar(1)/BB	-3.933	-2.896	-0.81	0.223	0.223
Line(1)	Lne	20.05	Single Busbar(1)/BB	3.472	2.675	0.79	0.201	0.201
			Single Busbar(2)/BB	-3.413	-2.645	-0.79	0.201	0.201
Line(10)	Lne	2.81	Single Busbar(10)/BB	0.515	0.244	0.90	0.028	0.028
			Single Busbar(11)/BB	-0.514	-0.244	-0.90	0.028	0.028
Line(11)	Lne	2.47	Single Busbar(11)/BB	0.454	0.209	0.91	0.025	0.025
			Single Busbar(12)/BB	-0.451	-0.207	-0.91	0.025	0.025
Line(12)	Lne	2.13	Single Busbar(12)/BB	0.391	0.172	0.92	0.021	0.021
			Single Busbar(13)/BB	-0.391	-0.171	-0.92	0.021	0.021
Line(13)	Lne	1.43	Single Busbar(13)/BB	0.271	0.091	0.95	0.014	0.014
			Single Busbar(14)/BB	-0.270	-0.091	-0.95	0.014	0.014
Line(14)	Lne	1.13	Single Busbar(14)/BB	0.210	0.081	0.93	0.011	0.011
			Single Busbar(15)/BB	-0.210	-0.080	-0.93	0.011	0.011
Line(15)	Lne	0.81	Single Busbar(15)/BB	0.150	0.060	0.93	0.008	0.008
			Single Busbar(16)/BB	-0.150	-0.060	-0.93	0.008	0.008
Line(16)	Lne	0.49	Single Busbar(16)/BB	0.090	0.040	0.91	0.005	0.005
			Single Busbar(17)/BB	-0.090	-0.040	-0.91	0.005	0.005
Line(17)	Lne	1.81	Single Busbar(1)/BB	0.361	0.161	0.91	0.018	0.018
			Single Busbar(18)/BB	-0.361	-0.161	-0.91	0.018	0.018
Line(18)	Lne	1.36	Single Busbar(18)/BB	0.271	0.121	0.91	0.014	0.014
			Single Busbar(19)/BB	-0.270	-0.120	-0.91	0.014	0.014
Line(19)	Lne	0.91	Single Busbar(19)/BB	0.180	0.080	0.91	0.009	0.009
			Single Busbar(20)/BB	-0.180	-0.080	-0.91	0.009	0.009
Line(2)	Lne	14.90	Single Busbar(2)/BB	2.383	2.148	0.74	0.149	0.149
			Single Busbar(3)/BB	-2.359	-2.135	-0.74	0.149	0.149
Line(20)	Lne	0.45	Single Busbar(20)/BB	0.090	0.040	0.91	0.005	0.005
			Single Busbar(21)/BB	-0.090	-0.040	-0.91	0.005	0.005
Line(21)	Lne	4.85	Single Busbar(2)/BB	0.940	0.457	0.90	0.049	0.049
			Single Busbar(22)/BB	-0.936	-0.455	-0.90	0.049	0.049
Line(22)	Lne	4.37	Single Busbar(22)/BB	0.846	0.405	0.90	0.044	0.044

Grid Freeze Ortho Snap Ln 135 Col 2 DB 5440 2/7/2106 10:28:15 AM 33bus

Figure 6. Line profile of IEEE 33 bus system

The bus voltage profile of IEEE 33 bus radial bus system is displayed in figure 7, showing volatge both in kilo volts and in per unit, angle in degrees.

Grid: Grid | System Stage: Grid | Study Case: Study Case | Annex: / 1

	rtd. V [kV]	Bus-voltage [p.u.]	Bus-voltage [kV]	[deg]	Generation [MW]	Generation [Mvar]	Motor Load [MW]	Motor Load [Mvar]	Load [MW]	Load [Mvar]	Ext. Infeed [MW]	Ext. Infeed [Mvar]	Compensation [Mvar]
Single Busbar(1)													
BB	12.66	1.00	7.29	0.03	0.00	0.00	0.00	0.00	0.10	0.06	0.00	0.00	0.00
Single Busbar(10)													
BB	12.66	0.92	6.75	0.18	0.00	0.00	0.00	0.00	0.04	0.03	0.00	0.00	0.00
Single Busbar(11)													
BB	12.66	0.92	6.74	0.19	0.00	0.00	0.00	0.00	0.06	0.03	0.00	0.00	0.00
Single Busbar(12)													
BB	12.66	0.92	6.70	0.09	0.00	0.00	0.00	0.00	0.06	0.03	0.00	0.00	0.00
Single Busbar(13)													
BB	12.66	0.91	6.68	0.02	0.00	0.00	0.00	0.00	0.12	0.08	0.00	0.00	0.00
Single Busbar(14)													
BB	12.66	0.91	6.67	-0.02	0.00	0.00	0.00	0.00	0.06	0.01	0.00	0.00	0.00
Single Busbar(15)													
BB	12.66	0.91	6.66	-0.05	0.00	0.00	0.00	0.00	0.06	0.02	0.00	0.00	0.00
Single Busbar(16)													
BB	12.66	0.91	6.65	-0.12	0.00	0.00	0.00	0.00	0.06	0.02	0.00	0.00	0.00
Single Busbar(17)													
BB	12.66	0.91	6.64	-0.13	0.00	0.00	0.00	0.00	0.09	0.04	0.00	0.00	0.00
Single Busbar(18)													
BB	12.66	1.00	7.28	0.02	0.00	0.00	0.00	0.00	0.09	0.04	0.00	0.00	0.00
Single Busbar(19)													
BB	12.66	0.99	7.26	-0.05	0.00	0.00	0.00	0.00	0.09	0.04	0.00	0.00	0.00
Single Busbar(2)													
BB	12.66	0.98	7.18	0.19	0.00	0.00	0.00	0.00	0.09	0.04	0.00	0.00	0.00
Single Busbar(20)													
BB	12.66	0.99	7.25	-0.07	0.00	0.00	0.00	0.00	0.09	0.04	0.00	0.00	0.00
Single Busbar(21)													
BB	12.66	0.99	7.25	-0.09	0.00	0.00	0.00	0.00	0.09	0.04	0.00	0.00	0.00
Single Busbar(22)													
BB	12.66	0.98	7.15	0.16	0.00	0.00	0.00	0.00	0.09	0.05	0.00	0.00	0.00

Figure 7. Bus voltage profile of IEEE 33 bus system

The under voltage profile of IEEE 33 bus radial bus system is displayed in figure 8, showing deviation of voltage in per unit.

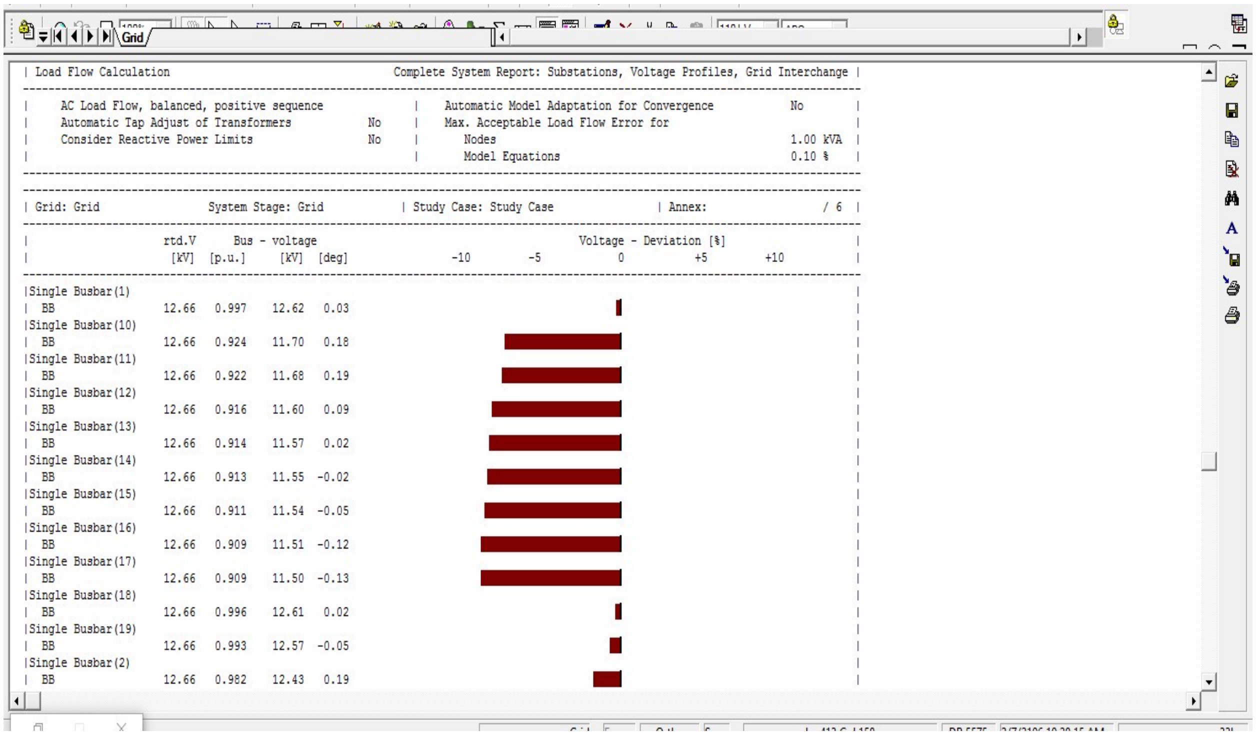


Figure 8. Under voltage profile of IEEE 33 bus system

The short circuit study of IEEE 33 bus radial bus system is displayed in figure 9, showing symmetrical current in kilo amperes and degree, apparent power, and short circuit current for the fault single phase to ground fault.

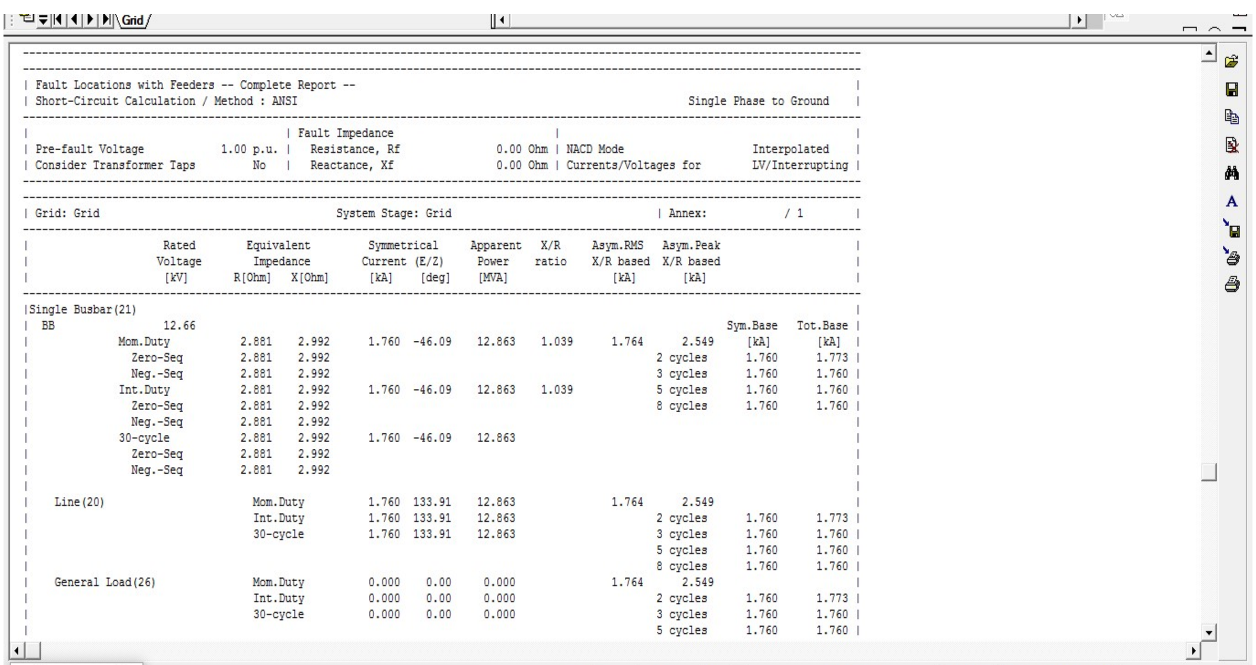
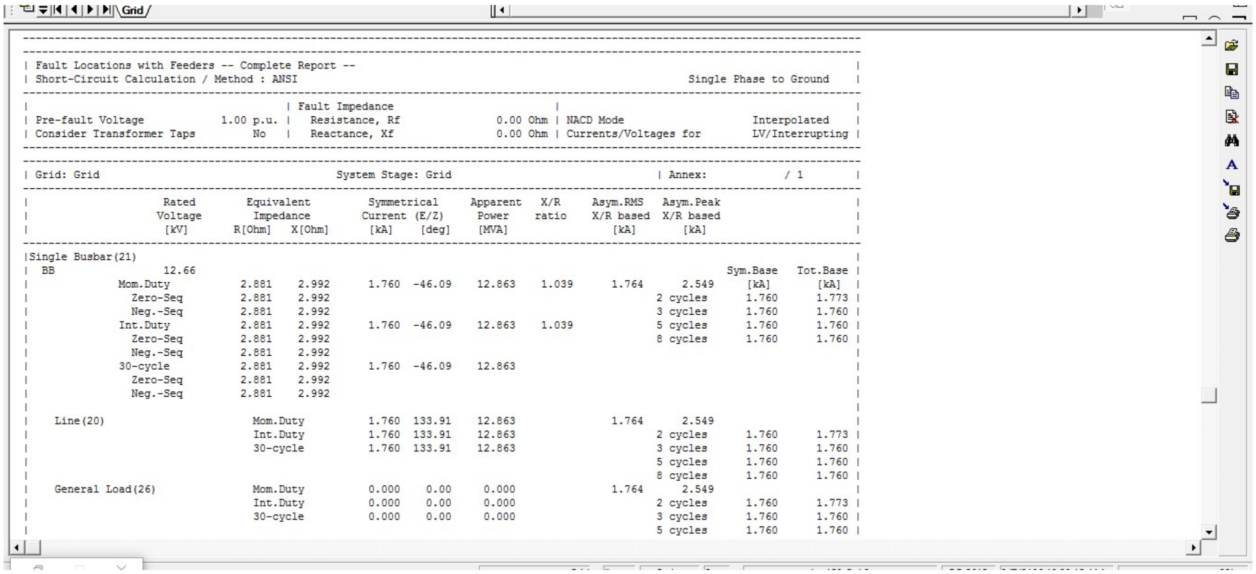


Figure 9. Short circuit result of IEEE 33 bus system

The optimal capacitor placement study of IEEE 33 bus radial bus system is displayed in figure 10.



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| Fault Locations with Feeders -- Complete Report --                                                        |
| Short-Circuit Calculation / Method : ANSI                                         Single Phase to Ground   |
|                                 | Fault Impedance                         |                                 |
| Pre-fault Voltage      1.00 p.u. |   Resistance, Rf            0.00 Ohm | NACD Mode              Interpolated |
| Consider Transformer Taps     No |   Reactance, Xf             0.00 Ohm | Currents/Voltages for  LV/Interrupting |

| Grid: Grid                             System Stage: Grid                        | Annex:          / 1   |

|              Rated      Equivalent        Symmetrical      Apparent   X/R     Asym.RMS   Asym.Peak        |
|              Voltage    Impedance         Current (E/Z)    Power      ratio   X/R based  X/R based        |
|              [kV]     R[Ohm]   X[Ohm]     [kA]    [deg]    [MVA]              [kA]       [kA]             |

|Single Busbar(21)                                                                                          |
|  BB            12.66                                                            Sym.Base   Tot.Base |
|         Mom.Duty        2.881    2.992     1.760  -46.09    12.863    1.039     1.764      2.549   [kA]       [kA]  |
|           Zero-Seq      2.881    2.992                                                  2 cycles   1.760      1.773 |
|           Neg.-Seq      2.881    2.992                                                  3 cycles   1.760      1.760 |
|         Int.Duty        2.881    2.992     1.760  -46.09    12.863    1.039              5 cycles   1.760      1.760 |
|           Zero-Seq      2.881    2.992                                                  8 cycles   1.760      1.760 |
|           Neg.-Seq      2.881    2.992                                                                        |
|         30-cycle        2.881    2.992     1.760  -46.09    12.863                                            |
|           Zero-Seq      2.881    2.992                                                                        |
|           Neg.-Seq      2.881    2.992                                                                        |
|                                                                                                              |
|   Line(20)                    Mom.Duty     1.760  133.91    12.863              1.764      2.549                   |
|                               Int.Duty     1.760  133.91    12.863                         2 cycles   1.760      1.773 |
|                               30-cycle     1.760  133.91    12.863                         3 cycles   1.760      1.760 |
|                                                                                            5 cycles   1.760      1.760 |
|                                                                                            8 cycles   1.760      1.760 |
|   General Load(26)            Mom.Duty     0.000    0.00     0.000              1.764      2.549                   |
|                               Int.Duty     0.000    0.00     0.000                         2 cycles   1.760      1.773 |
|                               30-cycle     0.000    0.00     0.000                         3 cycles   1.760      1.760 |
|                                                                                            5 cycles   1.760      1.760 |
```

Figure 10. Optimal capacitor placement of IEEE 33 bus system

IV.CONCLUSION

In this paper, the diagnostic result presented for the power flow analysis of IEEE 33 bus radial distribution system. In the load flow analysis, power losses of all components of distribution system obtained by simulating using power factory software. In short circuit study, prominent single phase to ground fault is activated and obtained the results. This result gives circuit breaker design and protected under any fault conditions. In IEEE 33 bus radial distribution system a particular bus has less voltage profile and improved by optimal capacitor placement. This work enhanced by designing transformer differential protection for IEEE 33 bus radial distribution system using DigSilent power factory software for effective protection under abnormal fault condition.

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