POWER FACTOR CORRECTION STUDY REPORT

A COMPARATIVE ANALYSIS USING DIGSILENT POWERFACTORY

POWER SYSTEMS ANALYSIS

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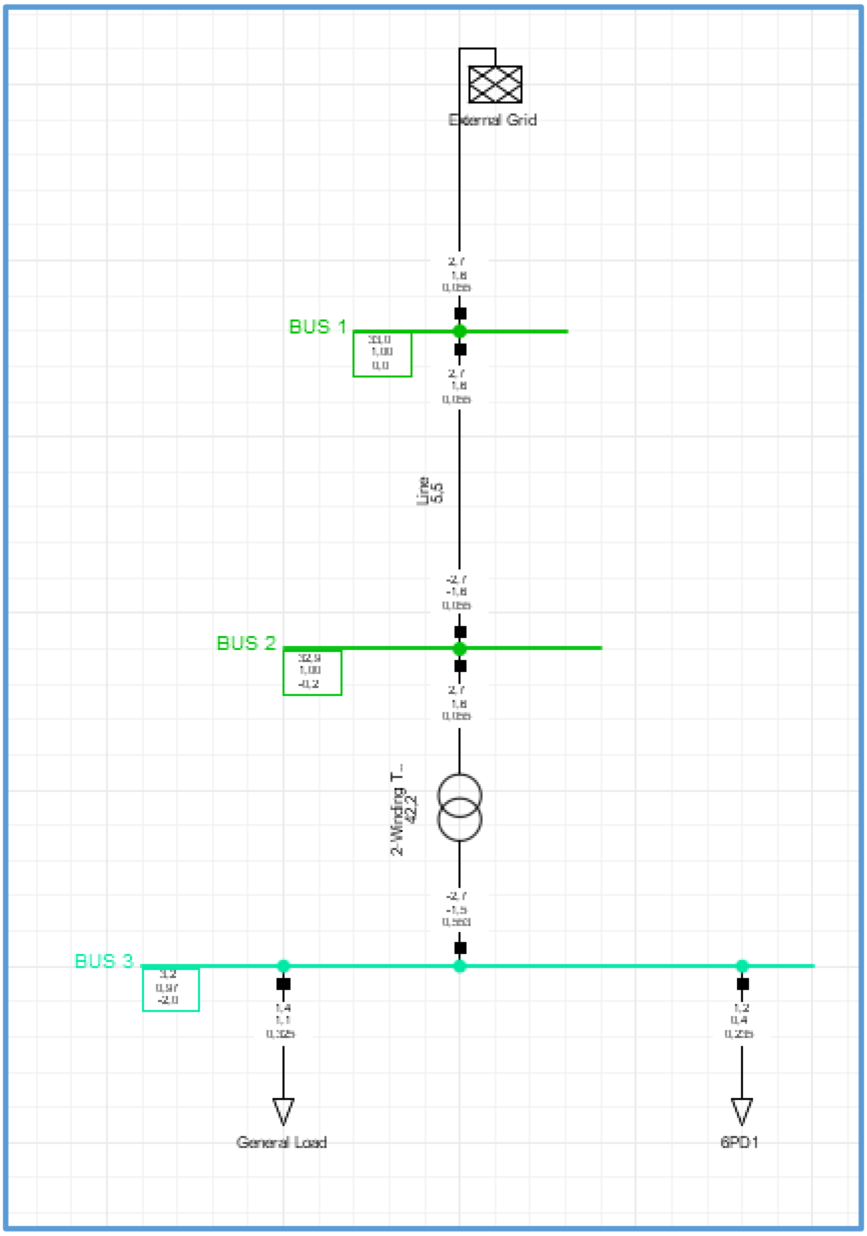
Introduction

This study focuses on the analysis and improvement of power factor in a simple three-bus radial feeder system. The feeder is supplied by an ideal 33 kV external grid feeding Bus 1, which connects to Bus 2 through a short distribution line represented by its series impedance. From Bus 2, a 7.5 MVA two-winding transformer steps the voltage down from 33 kV to 3.3 kV, supplying Bus 3 where the primary loads are connected. The downstream network consists of two major loads: a 1.8 MVA fixed-impedance load operating at 0.8 power factor lagging, and a 1.3 MVA non-linear (6PD1) load operating at 0.95 power factor lagging.

The initial load flow and short-circuit simulations were performed in both MATLAB and DIgSILENT PowerFactory to evaluate network voltages, power flows, and losses before and after compensation. In the uncompensated condition, all reactive power requirements were met by the source, resulting in a combined power factor of approximately 0.87 lagging at the point of common coupling (PCC) and a voltage at Bus 3 of about 0.97 per unit. To improve the reactive power balance and overall voltage profile, a shunt capacitor bank rated at approximately 0.62 MVAr was installed at Bus 3 (3.3 kV). The compensated case was then simulated to assess the improvement in power factor, reduction in reactive power flow, and enhancement in voltage regulation.

Simulation & Results



The model is a simple radial feeder. An ideal external grid at thirty three kilovolts supplies Bus 1, which connects to Bus 2 through a short line represented only by series impedance with resistance about zero point zero six seven one ohms and reactance about one point four two three ohms. From Bus 2 a two winding transformer rated seven point five MVA steps down from thirty three kilovolts to three point three kilovolts. Its positive sequence impedance is about two point five percent resistance and ten percent reactance which is roughly ten point three one percent short circuit voltage.

At Bus 3 the demand is split into two loads. Load 1 is a fixed impedance load of one point eight MVA at power factor zero point eight lagging. The second load 6PD1 represents a non-linear or electronic load of one point three MVA at power factor zero point nine five lagging. With no capacitor connected in this initial case reactive power must come from the source, so voltages fall from the slack bus toward Bus 3 to roughly zero point nine seven per unit and the combined power factor at the point of common coupling is about zero point eight seven lagging.

DIgSILENT PowerFactory 2025 SP1 | Project: | Date: 2025/10/11

Load Flow Calculation — Complete System Report: Voltage Profiles, Grid Interchange

AC Load Flow, balanced, positive sequence		Automatic Model Adaptation for Convergence	No
Automatic tap adjustment of transformers	No	Max. Acceptable Load Flow Error	
Consider reactive power limits	No	Bus Equations (HV)	1,00 kVA
		Model Equations	0,10 %

Grid: Grid | System Stage: Grid | Study Case: Study Case | Annex: / 2

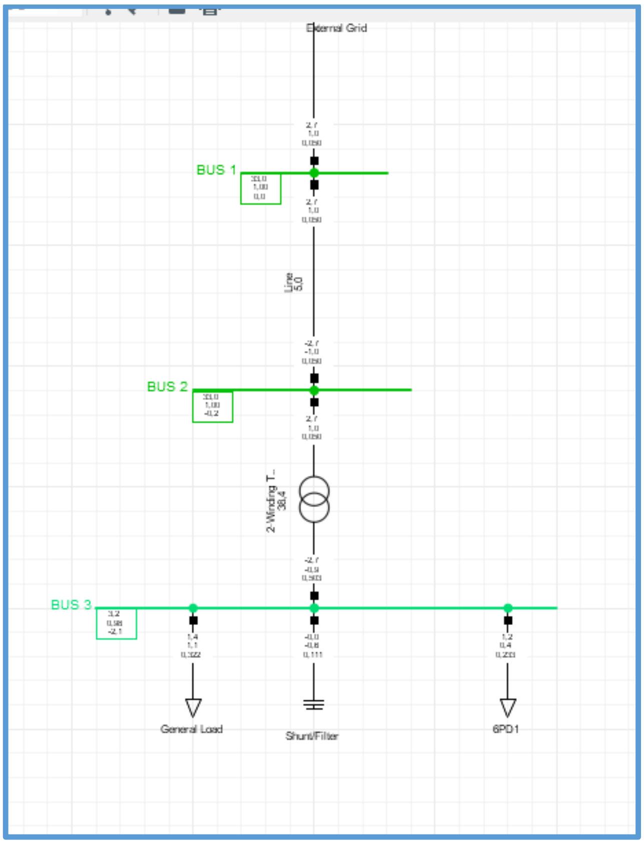
Volt. Level [kV]	Generation [MW]/ [Mvar]	Motor Load [MW]/ [Mvar]	Load [MW]/ [Mvar]	Compen-sation [MW]/ [Mvar]	External Infeed [MW]/ [Mvar]	Interchange to	Power Interchange [MW]/ [Mvar]	Total Losses [MW]/ [Mvar]	Load Losses [MW]/ [Mvar]	No load Losses [MW]/ [Mvar]
3,30	0,00	0,00	2,68	0,00	0,00			0,00	0,00	0,00
	0,00	0,00	1,49	0,00	0,00			0,00	0,00	0,00
						33,00 kV	-2,67	0,03	0,03	0,00
							-1,49	0,13	0,13	0,00
33,00	0,00	0,00	0,00	0,00	2,71			0,00	0,00	0,00
	0,00	0,00	0,00	0,00	1,63			0,01	0,01	0,00
						3,30 kV	2,71	0,03	0,03	0,00
							1,62	0,13	0,13	0,00
Total:	0,00	0,00	2,68	0,00	2,71		0,00	0,03	0,03	0,00
	0,00	0,00	1,49	0,00	1,63		0,00	0,15	0,15	0,00

Before compensation the feeder supplies 2.68 MW and 1.49 MVAr at Bus 3. The external grid provides about 2.71 MW and 1.63 MVAr to cover the load plus network losses, which are roughly 0.03 MW and 0.15 MVAr.

Total System Summary | Study Case: Study Case | Annex: / 3

	Generation [MW]/ [Mvar]	Motor Load [MW]/ [Mvar]	Load [MW]/ [Mvar]	Compen-sation [MW]/ [Mvar]	External Infeed [MW]/ [Mvar]	Inter Area Flow [MW]/ [Mvar]	Total Losses [MW]/ [Mvar]	Load Losses [MW]/ [Mvar]	No load Losses [MW]/ [Mvar]
\241297095\PRACTICAL_1\Network Model\Network Data\Grid									
	0,00	0,00	2,68	0,00	2,71	0,00	0,03	0,03	0,00
	0,00	0,00	1,49	0,00	1,63	0,00	0,15	0,15	0,00
Total:									
	0,00	0,00	2,68	0,00	2,71		0,03	0,03	0,00
	0,00	0,00	1,49	0,00	1,63		0,15	0,15	0,00

Voltages step down from the slack bus at about 33.8 kV to about 32.9 kV at Bus 2 and about 3.19 kV at Bus 3. The combined power factor at the point of common coupling is about 0.87 lagging, so Bus 3 is below 1.00 per unit before the capacitor is added.



This is the compensated case. A shunt capacitor bank is connected at Bus 3 at 3.3 kV and sized to about 0.62 to 0.63 MVAr. The upstream structure is unchanged: the 33 kV external grid feeds Bus 1, Line 1 links Bus 1 and Bus 2, and a 7.5 MVA 33 to 3.3 kV transformer supplies Bus 3. The loads remain the same at Bus 3, with the fixed impedance general load of 1.8 MVA at pf 0.80 lag and the 6PD1 load of 1.3 MVA at pf 0.95 lag.

With the capacitor on, reactive demand at Bus 3 is reduced from about 1.49 MVAr to roughly 0.87 to 0.90 MVAr. The point of common coupling power factor improves from about 0.87 lagging to about 0.95 lagging. External infeed reactive power falls from about 1.63 MVAr to about 0.99 to 1.02 MVAr, while real power remains about 2.70 MW. Bus 3 voltage rises from about 0.968 pu to about 0.977 pu, typically around 3.22 kV, and overall losses stay small at about 0.03 MW and 0.15 MVAr.

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|                |                                                              |   DIgSILENT   | Project:                   |
|                |                                                              | PowerFactory  |----------------------------
|                |                                                              |   2025 SP1    | Date:  2025/10/11          |
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| Load Flow Calculation                                     Complete System Report: Voltage Profiles, Grid Interchange |
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|    AC Load Flow, balanced, positive sequence              |    Automatic Model Adaptation for Convergence       No    |
|    Automatic tap adjustment of transformers        No     |    Max. Acceptable Load Flow Error                         |
                                                                                                                        5

|    Consider reactive power limits                  No     |      Bus Equations (HV)                          1,00 kVA  |
|                                                           |      Model Equations                             0,10 %    |
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| Total System Summary                                 | Study Case: Study Case              | Annex:               / 3  |
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|         Generation   Motor     Load    Compen-  External                 Inter Area    Total     Load   No load     |
|                       Load              sation   Infeed                     Flow      Losses    Losses   Losses     |
|            [MW]/     [MW]/     [MW]/    [MW]/     [MW]/                    [MW]/      [MW]/     [MW]/    [MW]/      |
|           [Mvar]    [Mvar]    [Mvar]   [Mvar]    [Mvar]                   [Mvar]     [Mvar]    [Mvar]   [Mvar]      |
---------------------------------------------------------------------------------------------------------------------
| \241297095\PRACTICAL_1\Network Model\Network Data\Grid                                                               |
|             0,00      0,00      2,68    -0,00      2,70                     0,00       0,03      0,03     0,00       |
|             0,00      0,00      1,49    -0,62      0,99                     0,00       0,12      0,12     0,00       |
---------------------------------------------------------------------------------------------------------------------
| Total:                                                                                                               |
|             0,00      0,00      2,68    -0,00      2,70                                0,03      0,03     0,00       |
|             0,00      0,00      1,49    -0,62      0,99                                0,12      0,12     0,00       |
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After adding the shunt capacitor at Bus 3, the report shows compensation of about 0.62 MVAr at 3.3 kV. The external grid now supplies about 2.70 MW and 0.99 MVAr, so the upstream reactive import has dropped by roughly 0.64 MVAr compared with the uncompensated case. Total network losses remain small at about 0.03 MW and 0.12 MVAr.

At the point of common coupling, the net load is now about 2.68 MW and 0.87 to 0.90 MVAr, which gives a power factor close to 0.95 lagging. In other words, the capacitor is supplying most of the local reactive demand at Bus 3, reducing reactive flow in the line and transformer and improving the voltage profile while leaving real power almost unchanged..

Conclusion

The power factor correction study demonstrated a significant improvement in system performance following the installation of the shunt capacitor at Bus 3. The local capacitor supplied most of the reactive power demand of the connected loads, reducing the total reactive import from the external grid from approximately 1.63 MVAr to about 1.00 MVAr. Consequently, the point of common coupling power factor improved from around 0.87 lagging to 0.95 lagging, while the voltage at Bus 3 rose from 0.968 pu to 0.977 pu (≈ 3.22 kV).

The results confirm that shunt compensation is an effective and economical method for improving power factor, minimizing reactive power flow through upstream components, and stabilizing voltage levels without altering real power delivery. Overall, the study highlights the practical importance of power factor correction in reducing network losses, enhancing system efficiency, and improving the voltage profile in medium-voltage distribution feeders.