Experiment No. 8,9,10 & 11

Design with Power Flow

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Introduction:

A nine-bus power system as shown in Appendix 2.1 was given, to be reduced to the least-power-loss system and the least-cost system.

To solve a power system, the Gauss-Siedel and Newton iterative methods are used, but for some situations, a solution doesn't exist. The base case contains a set of values for which a solution exists. Even though a solution can be found for the data in the base case, some of the resulting voltages and powers are not within the constraints given:

$0.95 < | V_I | < 1.05$ *p.u. (where* $I = 1, 2, \ldots n$, n *= number of buses)*
$P_{gi} < 110$ *MW, (*$I = 1, 2, \ldots$ *no. of generators)*
$P_{ij} < 100$ *MW, (*$I = 1, 2, \ldots$ *no. of lines)*

Compensation will be done on the base case to try to meet these constraints.

Procedure and Results:

Compensation:

Beginning with the base case in Appendix 2.1, compensation began with reallocation of the generator powers and voltages. Using reallocation alone could not satisfy all the voltage or complex power restraints. There were no excessive real powers, and there was one load bus voltage that met the restraints, but that was the best reallocation would allow. Refer to Appendix 2.2 for details.

Next, a few capacitor banks were added to the base case at various load buses, and using a trial and error process, they proved to do no good in meeting the constraints. They were observed to increase the bus voltages, which would be useful later. See Appendix 2.3 for the results.

The process of regulating transformers was then used, but did not help. It was observed, though, that transformers could possibly be used for decreasing or increasing the voltage on the secondary side – something that may be as useful as addition and deletion of capacitor banks.

The best case scenario was then derived using all three of the previous methods. Two capacitor banks were added to increase the bus voltages, and the tap ratio of the two transformers was adjusted (using trial and error) to give the least power loss.

Reduced Capital Costs:

As much equipment as possible was then removed from the power system. The two regulating transformers were removed (because they did very little in meeting the constraints), and also three redundant lines. By removing the lines, the power system became a *lot* less reliable, but the issue in this step was cost. Since the lines were the most costly equipment, removing as many as possible brought costs down a lot. See Appendix 3.1 for the base case of the reduced system.

Beginning with a base case that had a solution, the constraints were again attempted to be met. As with the same procedure as before, reallocation was done, but didn't meet any more constraints than the base case. The bus voltages were too low to begin with, and since the generators were already generating at a maximum voltage, there was very little that could be done. See Appendix 3.2 for the reallocation trial.

Next, capacitor banks were added to increase the bus voltages. With two banks, all the voltage constraints could be met, but two lines had gone above the power constraint. See Appendix 3.3

Since adding transformers wouldn't have a great effect on the voltages and powers, but would be costly, no regulating transformers were added.

Then reallocation and addition of capacitor banks were used to try to meet the constraints, but the power constraints couldn't be met. Another transmission line had to be added. After addition, the power constraints were met. The final solution can be found in Appendix 3.5. This design was still less in cost and power losses than the original design (before cost reduction), and it still met the restraints. See Appendix 1 for a cost comparison.

Conclusion:

In this lab we were given a power system and constraints, and we had to solve it (we were also given the loads and the line impedances). We investigated three methods of meeting the constraints (after finding generator voltages and powers that would give a convergent solution). Reallocation of the generator voltage and power was used (in general) to increase or decrease the load voltages. Adding capacitor banks was found to increase the load voltages, and of course, change the reactive power absorbed by the load. The regulating transformers were used to increase or decrease the load voltages.

In the second part of this project, we took out the equipment we thought was not absolutely necessary. This included taking out a few transmission lines, which made our system a lot less reliable. This is probably the way is it most of the time – a trade-off between reliability and cost.

The power losses were reduced by increasing the voltages as much as possible, because this reduced the current, which reduced the I^2R losses.

Appendix 1 - Attributes

Attributes:

	Lines	Transformers	Capacitor Banks	Reallocations	Total Cost	Power Losses*
Base Case	9	2	0	0	$9.2 M	0.1333 + j0.98650
Reallocation	9	2	0	2	$9.204 M	0.1384 + j1.0387
Capacitor Banks	9	2	2	0	$9.24 M	0.0844 + j0.3675
Regulating Transformers	9	2	0	0	$9.2 M	0.128 + j0.9089
Best Design Solution	9	2	2	0	$9.2 M	0.08480 + j0.3821
Reduced Base Case	6	0	1	0	$6.02 M	0.11080 + j0.8308
Reallocation	6	0	1	0	$6.02 M	0.11080 + j0.8308
Capacitor Banks	6	0	3	0	$6.06 M	0.0932 + j0.6299
Regulating Transformers	6	0	1	0	$6.02 M	0.11080 + j0.8308
Best Design Solution	7	0	2	0	$7.04 M	0.0823 + j0.4419 ***least losses***

* All power losses are in per unit.

Note: *Using capacitor banks gives the least power loss out of the three methods of compensation.*

Appendix 2.1 – Base Case Run

Appendix 2.2 – Reallocation Trial

Appendix 2.3 – Capacitor Bank Addition

Appendix 2.4 – Regulating Transformers

Appendix 2.5 – Best Design Solution

Appendix 3.1 – Base Case for Reduced System

Appendix 3.2 – Reallocation Trial

Appendix 3.3 – Capacitor Bank Addition

Appendix 3.4 – Regulating Transformers

Appendix 3.5 – Best Design Solution

Appendix 4.1 – Reduced Load Best Design Solution