Shunt Capacitors Placement in Kurdistan Region Power System Using Power Losses Index

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Abstract:

Capacitors in power systems are generally used to supply reactive power for the purpose of loss minimization and voltage profile improvement. The shunt capacitor allocation problem is the determination of the location of the capacitor to be placed in power system in a manner to reduce the total power losses of the networks. In this paper loss determination and capacitor placement is studied to reduce power loss in KRPS (Kurdistan Region Power System) using PSAT program under MATLAB Software. The capacitor placement problem aims to determine the locations of capacitors to be installed in a KRPS based on an index called power losses index (PLI) which it indicates the most effective candidate buses that the capacitor banks to be installed. The objective of the paper is aimed to reduce the power losses in the system and retain the voltage magnitudes of the system within prescribed maximum and minimum allowable values.

Keywords: Capacitor Location, Power Loss Reduction, Voltage Profile, KRPS, Power Losses Index (PLI).

I. Introduction:

The quantification and minimization of losses is important because it can lead to a more economic operation of a power system [1]. Technical losses are naturally occurring losses caused by actions internal to the power system and consist mainly of power dissipation in electrical system components such as transmission lines, power transformers, measurement systems [2], however transformer losses are not significant in such systems [1]. So transmission losses must be taken in to account. It is not possible to achieve zero losses in a power system, but it is possible to keep them at minimum; by means of reactive power compensation transmission system losses can be reduced [2].

Shunt capacitor placement in power systems is one of the most used schemes for reinforcement [3].

Capacitors in power systems are generally used to supply reactive power for the purpose of loss minimization and voltage profile improvement. The appropriate placement of capacitors is also important so as to ensure that system power loss and total capacitor costs can be reduced [4]. The amount of compensation provided is very much linked to the placement of capacitors in the power system which is essentially determination of the location, size, number and type of capacitors to be placed in the system [5].

A large variety of research work has been done on capacitor placement problem in the past. Different problem solution methods have been employed to solve the capacitor placement problem, such as, gradient search optimization, local variation method, optimization of equal area criteria method for fixed capacitors and dynamic programs [5].

II. Simulation with KRPS:

The real network of Kurdistan Region Power System was chosen as a test power network. The single line diagram of the network is given at appendix [6].

III. Description of the investigated KRPS:

Kurdistan region forms the three northern governorates of Iraq; they are Slemani, Erbil, Duhoke, and It is bounded by Iran from east, Turkey from north, and by Kirkuk, Diala and Mosel governorates from west and south.

The appendix illustrated KR 30-Bus HV power system (using PSAT Simulink library) which is consisting of 5 generation Buses, 25 load Buses and 42 HV transmission lines. Bus No. 1 is chosen as a slack Bus.

The power losses are one of the serious problems for the investigated for KRPS in general. The power system is old and mostly uncompensated in terms of reactive power. Due to the not adequate planning most of the equipments like transmission lines and transformers are overloaded during the peak-hours. Also many transmission lines are not the sizes that they are designed to be. As a result there are high losses and serious voltage drops at the ends of the lines in a system.

IV. Power system modeling and simulation:

The KRPS was modeled with the one voltage level of 132 kV. The power flow simulation software PSAT will be used for execution of power flows. After modeling of power grids the active power losses, buses voltage have been calculated.

In base Case, we can observe that the total system active and reactive losses are (0.317253, 0.679788) p.u. respectively.

In the second case, which is referred to increasing the load to a bought 1.2 of its base case, the losses are higher compared to the previous case as in this case there are many overloaded lines in our investigated grid. Keeping increasing load to 1.3 of its base case and according to our simulation results, the losses are higher (1.302002, 5.464716) p.u for total active and reactive losses respectively, and that's clear shown in Figure 1. Voltages of some substations are very low reaching 0.779661 as it's in bus number 29 and that's the reason for high losses in the system. In table 1, buses voltage and power losses are shown for base case and after increasing load.

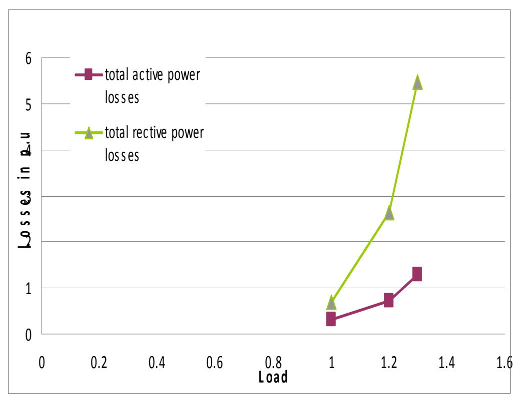

Figure1: Relation between increasing load and total active and reactive losses in the system.

VI. Candidate buses for the placement of capacitors

In this work an index called power losses index (PLI) is used, using equation (1) for determining PLI [7]. After performing the base case load flows, total active power loss of system is 31.7253 MW, then compensating the reactive power injection at candidate buses equal to 0.3 p.u at that particular bus, perform the load flows as for all cases and record the total active power loss and loss reduction of the system. This procedure is repeated for all remaining buses except slack bus and PV busses and results are tabulated in table (2).

$$PLI[i] = \frac{(Loss.reduction[i] - Min.Reduction)}{(Max.reduction - Min.Reduction)} \quad ....(1)$$

Now the best places for reactive power supports were defined. The identification of the candidate location of reactive power support is made using table (2).

The most suitable buses for the capacitor placement are chosen based on the condition that PLI must be greater than PLI tolerance value should be lies in between '0' and '1'. The tolerance value for a chosen system is selected by experimenting with different values in descending order of the PLI limits. The best value of the tolerance value gives the highest profit and satisfies the system constraints. Figure 3 shows variation of PLI for each bus in KRPS, and the best tolerance is set to 0.6 and it's concluded that buses 10,11,14,18, 19, 20,23,24,25, and 27 have PLI value greater than 0.6 that's clear in Figure 2. These are the most suitable candidate buses for insertion capacitor banks.

From the results it's clear that there is a decreasing in total active and reactive losses from 0.311432p.u to 0.660647p.u and from -1.418388p.u to 0.52437p.u. Respectively, Figure 2 shows' the results for this case.

Comparing table (1) and table (3) there is a significant improvement in voltage profiles of all buses in the system when the load increases.

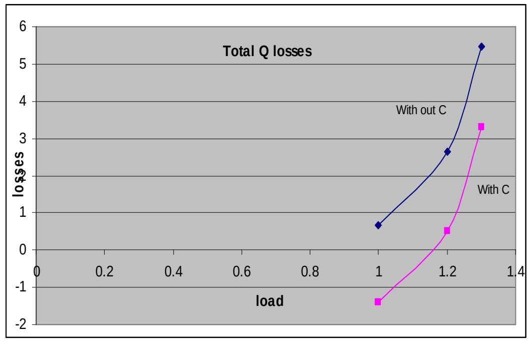

Figure2: Relation between increasing load and total reactive losses in the system with and without insertion capacitors.

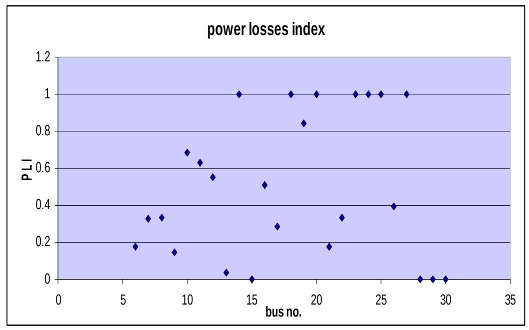

Figure 3: Variation of PLI for each bus in KRPS.

VII. Simulation results and their analysis:

Many iterations of PF have been performed. However, only the significant iterations will be shown in the following sub-sections.

Step-1: Performing PF for base case noting total losses and busses voltage.

Step-2: We will increase load at all load buses to 1.2 of its base case, perform a PF run, and calculate the total system loss, noting all buses voltages. As a result of increasing load, an increasing in active power loss from 0.317253p.u to 0.718774p.u and reactive power loss, from 0.679788p.u to 2.638007p.u was obtained.

Step-3: performing PF determining PLI for each bus; we can indicate the weakest buses of the system.

Step-4: We install a capacitor of 30 MVAr at the candidate position specified at step-3, increasing load as specified at step-2 again we perform a PF execution, calculating the total losses in the system,

Table (1): Buses voltage and power losses for base case and after increasing load.

.	Base case	load increased to 1.2 Base case	load increased to 1.3 Base case
Bus No	V[p.u.]	V[p.u.]	V[p.u.]
Bus 01	1	1	1
Bus 02	1	1	1
Bus 03	1	1	1
Bus 04	0.98	0.98	0.98
Bus 05	0.97	0.97	0.97
Bus 06	0.950805	0.927503	0.91529
Bus 07	0.957187	0.928018	0.908456
Bus 08	0.969689	0.941079	0.918319
Bus 09	0.979624	0.94428	0.920201
Bus 10	0.96238	0.913224	0.877018
Bus 11	0.957451	0.904971	0.865775
Bus 12	0.956634	0.903022	0.863169
Bus 13	0.996635	0.992212	0.988452
Bus 14	0.969482	0.941396	0.915386
Bus 15	0.979801	0.9792	0.9789
Bus 16	0.959642	0.924475	0.902206
Bus 17	0.967072	0.947949	0.936525
Bus 18	0.94063	0.8541	0.798849
Bus 19	0.956129	0.904335	0.87136
Bus 20	0.978226	0.961388	0.949741
Bus 21	0.99431	0.989747	0.986756
Bus 22	0.981195	0.966099	0.954761
Bus 23	0.981487	0.966904	0.956205
Bus 24	0.963919	0.920798	0.893079
Bus 25	0.982352	0.96431	0.952739
Bus 26	0.992864	0.983494	0.978722
Bus 27	0.979042	0.946784	0.927615
Bus 28	0.997162	0.990507	0.986584
Bus 29	0.940785	0.842343	0.779661
Bus 30	0.998175	0.96726	0.950479
PT L	0.317253	0.718774	1.302002
QTL	0.679788	2.638007	5.464716

Table (2): Buses voltage and power losses for base case and after increasing load with insertion a capacitor of 0.3 p.u.

	0.3 capacitor is inserted at candidate buses		
Bus No.	Base case	load increased to 1.2 Base case	load increased to 1.3 Base case
	V[p.u.]	V[p.u.]	V[p.u.]
Bus 06	0.950805	0.927503	0.91529
Bus 07	0.958401	0.930379	0.911408
Bus 08	0.972139	0.945723	0.924028
Bus 09	0.989401	0.945577	0.917682
Bus 10	0.986341	0.916311	0.869868
Bus 11	0.987106	0.905769	0.851714
Bus 12	0.986926	0.904384	0.849594
Bus 13	0.997013	0.992955	0.989307
Bus 14	0.975185	0.952314	0.929139
Bus 15	0.979801	0.9792	0.9789
Bus 16	0.975113	0.940221	0.918486
Bus 17	0.970151	0.951105	0.939806
Bus 18	1.00025	0.914282	0.860451
Bus 19	0.993631	0.942192	0.909938
Bus 20	0.987713	0.971207	0.959907
Bus 21	0.996347	0.991861	0.988948
Bus 22	0.988697	0.974117	0.963222
Bus 23	0.989038	0.974889	0.964568
Bus 24	0.990127	0.947224	0.919808
Bus 25	0.99448	0.976372	0.964839
Bus 26	0.992864	0.983494	0.978722
Bus 27	0.99927	0.966973	0.947853
Bus 28	0.999462	0.99281	0.988903
Bus 29	1.006532	0.908924	0.847979
Bus 30	1.000477	0.969626	0.952896
PTL	0.311432	0.660647	1.201687
QTL	-1.41838	0.52437	3.300995

Table (3): Buses Loss reduction and PLI.

Base case total power loss	31.7253		
Bus number	Total active power loss reduction after compensating Qc at each bus (MW)	Loss reduction	PLI
Bus 06	31.69054	0.034756	0.176506
Bus 07	31.66043	0.064874	0.329476
Bus 08	31.65984	0.065461	0.33246
Bus 09	31.69638	0.028922	0.146878
Bus 10	31.59065	0.134646	0.683844
Bus 11	31.60062	0.124682	0.633237
Bus 12	31.61682	0.10848	0.550947
Bus 13	31.71807	0.007234	0.036728
Bus 14	31.52841	0.196894	1
Bus 15	31.7252	9.82E-05	0.000584
Bus 16	31.64201	0.083286	0.510926
Bus 17	31.67879	0.046515	0.285342
Bus 18	31.56229	0.163007	1
Bus 19	31.59596	0.129341	0.843457
Bus 20	31.57195	0.153345	1
Bus 21	31.70488	0.020418	0.173501
Bus 22	31.68625	0.03905	0.331841
Bus 23	31.60763	0.11767	1
Bus 24	31.65261	0.072688	1
Bus 25	31.67397	0.051326	1
Bus 26	31.71836	0.006939	0.393474
Bus 27	31.70767	0.01763	1
Bus 28	31.7253	2.9E-06	0
Bus 29	31.7253	2.9E-06	0
Bus 30	31.7253	2.9E-06	0

IX. Conclusions:

The presented results in this paper have shown that the optimal placement of shunt capacitor banks have been determined, the method was implemented on the tested of real power grid of KRPS using the proposed PLI, A load flow study can be used to calculate the MW and the MVar flows in power system, determine operating voltage levels for selected operating conditions, the simulation has been done for the base case operations and when the system is heavily loaded.

The determined optimal location has reduced the system energy losses, and improves voltage profiles of all buses significantly.

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Appendix - Diagram of 30 – Bus KRPS