OPTIMAL ALLOCATION OF FIXED CAPACITOR FOR DISTRIBUTION SYSTEM

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THIS REPORT IS SUBMITTED IN PARTIAL FULFILLMENT OF REQUIREMENTS FOR THE DEGREE OF BACHELOR IN ELECTRICAL ENGINEERING (POWER INDUSTRY)

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"Saya/~~kami~~* akui bahawa saya telah membaca karya ini pada pandangan saya/~~kami~~ karya ini adalah memadai dari skop dan kualiti untuk tujuan penganugerahan Ijazah Sarjana Muda Kepujian Elektrik (Kuasa Industri)."

Tandatangan : ....

Nama Penyelia : PUAN AIDA FAZLIANA BINTI ABDUL KADIR

Tarikh : 10/3/05

"I admitted that this project is written by me and is my own effort and that no part has been plagiarized without citations".

Tandatangan : ....

Nama Penulis : MOHD NAJIB BIN MOHD YUSOF

Tarikh : 10 MARCH 2005

For my beloved mother

Maimunah Binti Mahmod

In appreciation of supported and understanding

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ABSTRACT

This project presents an optimal capacitor placement that simplified by load flow simulation and calculation. Many methods have been proposed over the last thirty-five years using different models and mathematical solution techniques. The objectives of this project are to identify optimal allocation of fixed capacitor, which determines the size and location of capacitor to be installed at distribution system. This capacitor compensation will reduce energy losses, improve power factor of the system and increase the power transmission capability. This project has been applied to the IEEE test system and real system using ERACS software that suite power system analysis.

ABSTRAK

Projek ini membincangkan kaedah peletakan kapasitor yang optimum melalui simulasi analisis aliran kuasa dan juga pengiraan. Dalam tempoh 35 tahun yang lepas, banyak kaedah dan juga pendekatan penyelesaian yang ditemui dimana melibatkan banyak jenis model dan juga teknik penyelesaian matematik. Matlamat utama projek ini adalah untuk memperolehi dan mengenalpasti kedudukan optimum sesebuah kapasistor tetap melalui penentuan saiz dan lokasi kapasitor yang hendak diletakkan dalam sistem pengagihan. Hasil daripada pemampasan kapasitor ini akan mengurangkan kehilangan tenaga, meningkatkan faktor kuasa sesebuah sistem dan juga meningkatkan kadar kebolehan penghantaran kuasa. Projek ini telah diterapkan kepada IEEE sistem ujian dan juga sistem sebenar dengan menggunakan perisisan ERACS yang sesuai untuk analisis sistem kuasa.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Capacitors have been very commonly used to provide reactive power compensation in distribution system. They are provided to minimize power and energy losses, maintain best voltage regulations for load busses and improve the system. It is essentially for determination of the location and size of capacitors to be placed in the system.

Optimal capacitor placement allows engineers to strategically place capacitors for voltage support and power factor correction while minimizing installation and long-term operation costs. The advanced graphical interface gives users the flexibility to control the capacitor placement process and graphically view the results. The precise calculation approach automatically determines the best locations and bank sizes. In addition, it reports the branch capacity release and the estimated savings during the planning period due to var loss reduction.

Computer applications in electric distribution systems are quite common in distribution system expansion planning and optimal capacitor allocation. These studies require knowledge of the actual reactive power and power factor correction (PFC) demands at each load of the distribution system.

The application of capacitors for power factor (PF) improvement is quite common in industrial plants and commercial establishments. Similarly, capacitors are commonly used by electric utilities for feeder voltage control and for efficiency improvement of the distribution system. If a distribution system has a low power factor, more current must flow through power distribution lines. Energy and money is wasted due to additional energy being required for non-productive purposes.

One of the outstanding and major problems in the distribution system is the loss that causes energy losses. In power system operation, the tendency is to maximize the real power transmission line, bring the voltage profile within tolerance and reduce the system losses. However, a certain critical voltage level limits increase of real power transmission in a particular system. This critical voltage is dependent on the reactive power support available in the system to meet the additional load in that operating condition.

Power provided and maintained for the explicit purpose of insuring continuous, steady voltage on transmission networks. Reactive power is energy, which must be produced for maintenance of the system and is not produced for end-use consumption. Electric motors, electromagnetic generators and alternators used for creating alternating current are all components of the energy delivery chain, which require reactive power. Losses incurred in transmission from heat and electromagnetic emissions are included in total reactive power. This power is supplied for many purposes by capacitors and similar devices that can react to changes in current flow by releasing energy to normalize the flow, and regulating generators may also have this capability.

Optimal capacitor placement, consideration of active loads such as induction motor and passive load such as lighting purpose need to look after. Sizing of capacitor also important for correct power factor (PF). For example, the capacitor of motor will not run properly with a weak capacitor. This is not to imply bigger is better, because a capacitor that is too large can cause energy consumption to rise. In both instances, be it too large or too small, the life of the motor will be shortened due to overheated motor windings.

There are several type of capacitor need to considered such as shunt capacitors, series capacitors, filter capacitors and static var compensation (SVC) capacitors. Normally shunt fixed capacitor is used on lower voltage at distribution system but for series capacitors and SVC capacitors is used on transmission voltages because of need for reactive power and voltage regulation. Judiciously applied shunt capacitors can boost power factor, reduce system losses, enhance voltage regulation, and release system capacity for new load.

The application of capacitors for power factor correction and voltage support must be carefully considered to prevent operating difficulties and potentially damaging over voltages. System load variations and the type of loads served must be evaluated in the analysis. Each system is unique and solutions should be modeled on a computer to determine the optimum type of capacitor system, amounts of correction needed and where it should be installed. Several different analytical tools and computer programs (E-RACS software) can utilize for the evaluation of electrical systems and determination of the best and safest approach to power factor improvement.

1.2 Project Objective and Scope

1.2.1 To find optimal allocation of fixed capacitor in power system network.

The aim of this project is to determine optimal capacitor placement. It will consider the size, type and location of capacitor to be installed at distribution system. This placement applied at test system and real system under load flow simulation. The load flow module calculates the steady state conditions of the power system network. Under given constraints the program will determine the network voltage profile, power factor, real power and reactive power flows.

1.2.2 To analyze system with and without capacitor at distribution system.

Capacitor used to provide reactive power compensation in distribution system. It is important for analyzing the system before and after addition of capacitor. The solution procedure start off with performing a simplified power flow study to calculate size of capacitor and reactive power compensation that been provided by capacitor.

1.2.3 To improve power factor of the system due to addition of capacitor.

Power factor improvement is the main purpose for capacitor installation. It will give the positive effect to the system such as increased transmission capability and reduced transmission losses. Power factor of at each load and at the main intake need to take account for improve power system efficiency. This positive changing of power factor is called 'power factor correction'.

CHAPTER 2

LITERATURE REVIEW

Several studies have been conducted over the last thirty-five years, and there have been many proposed method using different models and mathematical solution techniques to solve the capacitor placement problem such as sensitivity based optimal [2], distribution-analyzer-recorder, genetic algorithms (GA) [1] and etc. Use of shunt compensation is some of the remedial measures suggested for this method. Test system and real system has been applied in distribution power system. This method is very well known and capable method for optimization problems. It is capable of determining and solving suitable fixed capacitor placement problem.

The proposed method allows design a distribution system to select the optimal allocation of the fixed capacitor size and location. Design of distribution system model using E-RACS software with different fixed capacitor placement is considered in the system simulation. In this method, constant power, constant current and constant impedance is considered because selection of fixed capacitor is to be install in distribution system. The proposed method will effect power factor correction and power transmission capability.

The proposed optimal fixed capacitor placement simulation is to determine the actual condition happen at distribution systems. In order to accurately simulate the distribution systems, it is vitally important to take into account the parameter such as reactive power, power factor and terminal voltage.

2.1 Type of Capacitor

2.1.1 Shunt capacitors

Shunt capacitor installed in transmission and distribution networks will increase transmission capability, reduce losses and improve the power factor. Shunt capacitors are primarily used to improve the power factor (cos ϕ) in the network.

Active load such as induction motors consume reactive power and needed is generated by capacitors. By applying capacitors adjacent to equipment consuming reactive power, several advantages are obtained such as improved power factor of the system, reduced the transmission losses and improved power quality.

2.1.2 Series capacitors

Series capacitors in transmission systems increase power transfer capability and reduce losses. Series capacitors are also installed in distribution systems, mainly to improve the voltage stability.

Series compensation of a network positively affects the voltage and the reactive power balance. When the load currents passes through the capacitor, the voltage drop over capacitor varies in proportion to the current.

The voltage drop is capacitive, i.e. it compensates the inductive voltage drop, which also varies with the load current. The result is an automatic stabilizing effect on the voltage in a network.

2.1.3 Filter capacitors

Many of the loads in a power network such as converters, rectifiers, welding equipment and arc furnaces generate harmonics. Increased losses and damage to electronic equipment are among the problems that may occur. Harmonic filters eliminate the problem by reducing the harmonic content in the network and also improve the power factor by generating reactive power.

Modern electrical equipment generates harmonic currents, which are transmitted to the supply network. Most of the harmonics arise from electronically controlled equipment such as converters, variable speed drives, static converters, welding equipment etc. but also from arc furnace. Among the problems that may occur due to excessive harmonic currents are increased losses in motors, transformers, and cables. It may lead to overheating, overloading of capacitors, damage to or malfunction in electronic equipment, malfunction of receiver relays in ripple control system and interference with telephone circuits.

2.1.4 Static var compensator (SVC) capacitors

In static var compensation (SVC) thyristors are used for switching and control of capacitors and reactors. Instant transient -free switching is obtained, as well as continuously variable control of the reactive power. Static var compensators in transmission systems increase the transmission capacity; improve voltage control and stability, and damp power swings due to network faults or tripping of heavy loads in interconnected systems.

They are also used in distribution systems and for difficult loads, e.g. arc furnaces, where asymmetrical fluctuations in the current occur due to the instability of the consumption of the arc. Fluctuations in current resulting in variations in the consumption of reactive power can be controlled and the furnace is provided with more active power, thus increasing productivity.

2.1.5 HVDC capacitors

Power capacitors from an important part of an HVDC transmission system for harmonic filtering as well as supply of reactive power. Capacitors with high quality and reliability are essential to the overall performance of the system.

HVDC capacitors uses the self-protected where can be either of a patented fuseless design or equipped with internal fuses. The self-protected design offers advantages of vital importance for all applications where high reliability is an absolute necessity, such as in HVDC systems.

Single element failures do not affect the performance and protection coordination is easier, enabling increased selectivity compared to other protection solutions. High quality and reliability not only improve the electrical performance of the capacitors, also the ability to resist severe climatic and seismic conditions is enhanced.

2.2 Size of Capacitor

Sizing of a fixed capacitor required to achieve a utility mandated power factor is simple, as shown in Figure 1. Systems with small differences between minimum and maximum loading can be designed for the average loading and fixed (non switched) capacitors can be applied.

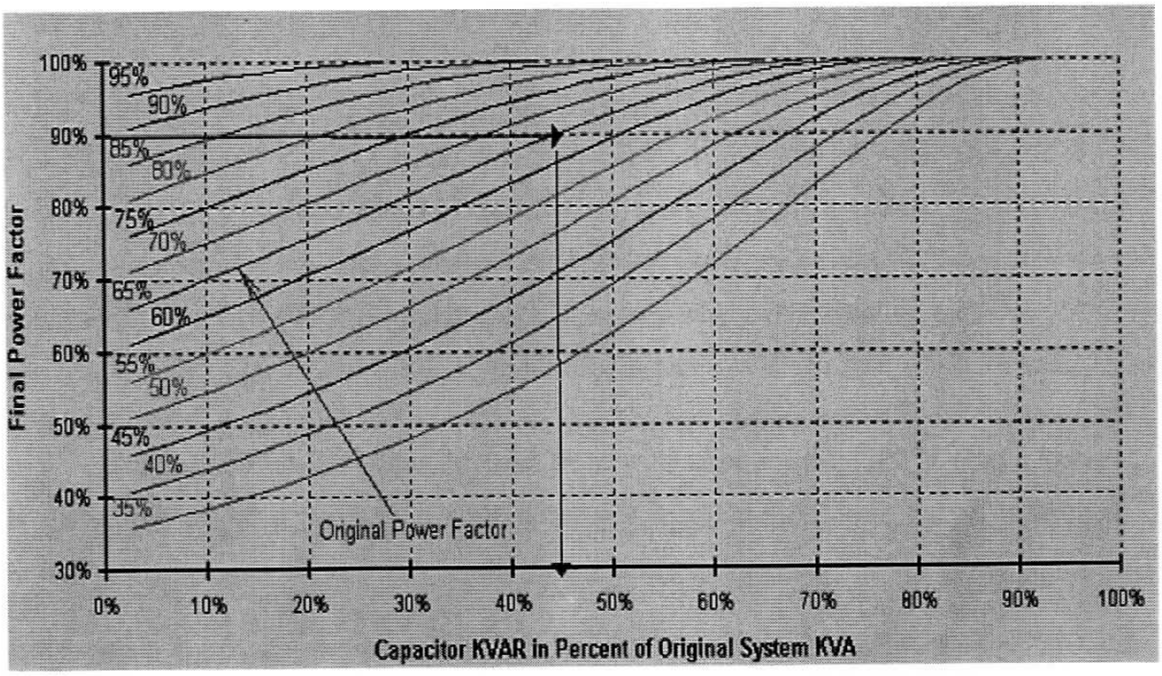

Figure 1: Final power factor as a function of added capacitor size

Figure 1 is provided for quick estimation of the additional kVAR needed to achieve a higher power factor. To use Figure 1, draw a horizontal line from the desired PF to intersect with the curve corresponding to the original PF. Extend a vertical line down to the horizontal axis and read the value for the required capacitor bank (given in percent of the original load kVA). Example of the use of Figure 1: Original kVA of system 2500, Original PF = 65% Required capacitor size = 1100 kVAR (44% of 2500 kVA) for a desired PF of 90%.

We can also determine the overall KVAR requirements, when the normal load KW and the original power factor known. This information can usually be obtained from the electric utility bill or from the local power company. To compute the total KVAR, required, refer to Table 1, and multiply the value found at the intersection of "Original Power Factor" and "Desired Power Factor" by the normal loads KW. As an example to improve the power factor of a 400 KW load from 0.77 to 0.92:

KVAR = KW x Multiplier

= 400 x 0.403 (Table 3)

= 161.2

Example: Total KW-input of load from wattmeter reading 100 KW at a power factor of 65%. The capacitive KVAR necessary to raise the power factor to 95% is found by multiplying the 100 KW by the factor found in the table (0.840). Then 100 KW x 0.840 = 84 KVAR. Use 85 KVAR.

Table 1: Kilowatts Multipliers for Determining Capacitor Kilovars

Original Power Factor	Desired Power Factor																			
	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.88	0.89	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1.00
0.51	.962	.989	1.015	1.041	1.067	1.094	1.120	1.147	1.175	1.203	1.231	1.261	1.292	1.324	1.358	1.395	1.436	1.484	1.544	1.687
0.52	.919	.945	.971	.997	1.023	1.050	1.076	1.103	1.131	1.159	1.187	1.217	1.248	1.280	1.314	1.351	1.392	1.440	1.500	1.643
0.53	.876	.902	.928	.954	.980	1.007	1.033	1.060	1.088	1.116	1.144	1.174	1.205	1.237	1.271	1.308	1.349	1.397	1.457	1.600
0.54	.835	.861	.887	.913	.939	.966	.992	1.019	1.047	1.075	1.103	1.133	1.164	1.196	1.230	1.267	1.308	1.356	1.416	1559
0.55	.795	.821	.847	.873	.899	.926	.952	.979	1.007	1.035	1.063	1.093	1.124	1.156	1.190	1.227	1.268	1.316	1.377	1.519
0.56	.756	.782	.808	.834	.860	.887	.913	.940	.968	.996	1.024	1.054	1.085	1.117	1.151	1.188	1.229	1.277	1.338	1.480
0.57	.718	.744	.770	.796	.822	.849	.875	.902	.930	.958	.986	1.016	1.047	1.079	1.113	1.150	1.191	1.239	1.300	1.442
0.58	.681	.707	.733	.759	.785	.812	.838	.865	.893	.921	.949	.979	1.010	1.042	1.076	1.113	1.154	1.202	1.263	1.405
0.59	.645	.671	.697	.723	.749	.776	.802	.829	.857	.885	.913	.943	.974	1.006	1.040	1.077	1.118	1.166	1.226	1.368
0.60	.609	.635	.661	.687	.713	.740	.766	.793	.821	.849	.877	.907	.938	.970	1.004	1.041	1.082	1.130	1.192	1.334
0.61	.575	.601	.627	.653	.679	.706	.732	.759	.787	.815	.843	.873	.904	.936	.970	1.007	1.048	1.096	1.157	1.299
0.62	.542	.568	.594	.620	.646	.673	.699	.726	.754	.782	.810	.840	.871	.903	.937	.974	1.015	1.063	1.123	1.265
0.63	.509	.535	.561	.587	.613	.640	.666	.693	.721	.749	.777	.807	.838	.870	.904	.941	.982	1.030	1.091	1.233
0.64	.474	.503	.529	.555	.581	.608	.634	.661	.689	.717	.745	.775	.806	.838	.872	.909	.950	.998	1.068	1.200
0.65	.445	.471	.497	.523	.549	.576	.602	.629	.657	.685	.713	.743	.774	.806	.840	.877	.918	.966	1.027	1.169
0.66	.414	.440	.466	.492	.518	.545	.571	.598	.626	.654	.682	.712	.743	.775	.809	.846	.887	.935	.996	1.138
0.67	.384	.410	.436	.462	.488	.515	.541	.568	.596	.624	.652	.682	.713	.745	.779	.816	.857	.905	.966	1.108
0.68	.354	.380	.406	.432	.458	.485	.511	.538	.566	.594	.622	.652	.683	.715	.749	.786	.827	.875	.937	1.079
0.69	.325	.351	.377	.403	.429	.456	.482	.509	.537	.565	.593	.623	.654	.686	.720	.757	.798	.846	.907	1.049
0.70	.296	.322	.348	.374	.400	.427	.453	.480	.508	.536	.564	.594	.625	.657	.691	.728	.769	.817	.878	1.020
0.71	.268	.294	.320	.346	.372	.399	.425	.452	.480	.508	.536	.566	.597	.629	.663	.700	.741	.789	.850	.992
0.72	.240	.266	.292	.318	.344	.371	.397	.424	.452	.480	.508	.538	.569	.601	.635	.672	.713	.761	.821	.963
0.73	.212	.238	.264	.290	.316	.343	.369	.396	.424	.452	.480	.510	.541	.573	.607	.644	.685	.733	.794	.936
0.74	.185	.211	.237	.263	.289	.316	.342	.369	.397	.425	.453	.483	.514	.546	.580	.617	.658	.706	.767	.909
0.75	.158	.184	.210	.236	.262	.289	.315	.342	.370	.398	.426	.456	.487	.519	.553	.590	.631	.679	.740	.882
0.76	.131	.157	.183	.209	.235	.262	.288	.315	.343	.371	.399	.429	.460	.492	.526	.563	.604	.652	.713	.855
0.77	.105	.131	.157	.183	.209	.236	.262	.289	.317	.345	.373	.403	.434	.466	.500	.537	.578	.626	.687	.829
0.78	.078	.104	.130	.156	.182	.209	.235	.262	.290	.318	.346	.376	.407	.439	.473	.510	.551	.599	.661	.803
0.79	.052	.078	.104	.130	.156	.183	.209	.236	.264	.292	.320	.350	.381	.413	.447	.484	.525	.573	.634	.776
0.80	.026	.052	.078	.104	.130	.157	.183	.210	.238	.266	.294	.324	.355	.387	.421	.458	.499	.547	.608	.750
0.81	.000	.026	.052	.078	.104	.131	.157	.184	.212	.240	.268	.298	.329	.361	.395	.432	.473	.521	.582	.724
0.82		.000	.026	.052	.078	.105	.131	.158	.186	.214	.242	.272	.303	.335	.369	.406	.447	.495	.556	.698
0.83			.000	.026	.052	.079	.105	.132	.160	.188	.216	.246	.277	.309	.343	.380	.421	.469	.530	.672
0.84				.000	.026	.053	.079	.106	.134	.162	.190	.220	.251	.283	.317	.354	.395	.443	.504	.645
0.85					.000	.027	.053	.080	.108	.136	.164	.194	.225	.257	.291	.328	.369	.417	.478	.620
0.86						.000	.026	.053	.081	.109	.137	.167	.198	.230	.264	.301	.342	.390	.451	.593
0.87							.000	.027	.055	.083	.111	.141	.172	.204	.238	.275	.316	.364	.425	.567
0.88								.000	.028	.056	.084	.114	.145	.177	.211	.248	.289	.337	.398	.540
0.89									.000	.028	.056	.086	.117	.149	.183	.220	.261	.309	.370	.512
0.90										.000	.028	.058	.089	.121	.155	.192	.233	.281	.342	.484
0.91											.000	.030	.061	.093	.127	.164	.205	.253	.314	.456
0.92												.000	.031	.063	.097	.134	.175	.223	.284	.426