OPTIMAL CAPACITOR PLACEMENT IN RADIAL DISTRIBUTION SYSTEM USING HARMONY SEARCH ALGORITHM

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To my beloved parents,

Mohamad Rusli B Omar & Robitah Bt Ambri

To my thoughtful siblings, sister and brother in law,

Nur Ezzatin, Nur Hafeela & Mohd Fadzli

To my supportive supervisor,

AP Dr. Mohd Wazir Bin Mustafa

To my gracious aunts & coolest friends,

UTMians

To special person in my life,

Yusheila Bt Md Yunus

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ABSTRACT

Modern electric energy are generated from generating station and it deliver to the customer through transmission and distribution network. Most electrical equipment such as motors, lamps and heaters required constant voltage in order to operate. Transmission and distribution system are not required to carry active power but it must also carry magnetizing for inductive load at consumer side. It is essential that the generator at generating station produce active and reactive power. In order to supply and produce reactive power, shunt capacitor are widely used. There are several benefit of shunt capacitor installation in distribution system such as reactive power compensation, power factor correction, system capacity released , power support , reduction in loss and voltage improvement. In this study, the placement of shunt capacitor and optimal capacitor size will be carried out. The result are then compare with others technique in term of capacitor installation cost saving. In this study, loss reduction and voltage profile improvement are studied. It is shown that almost 14% of the losses contribute at distribution system. It also very important to determine the appropriate location of capacitor in order to reduce the system power loss and total capacitor cost. In this study, the main objective is to find the optimal capacitor placement using a new meta-heuristic approach, Harmony Search Algorithm in radial distribution system which is then to reduce power loss and improve the system voltage profile. Simple backward forward sweep power flow is used to determine the power flow in the system. The performance of proposed algorithm is test using 9 bus system and compare with other meta-heuristic approach, Particle Swarm Optimization.

ABSTRAK

Tenaga elektrik moden yang dijana daripada stesen janakuasa dan ia disalurkan kepada pelanggan melalui rangkaian penghantaran dan pengedaran. Peralatan yang elektrik seperti motor, lampu dan pemanas memerlukan voltan malar untuk beroperasi. Penghantaran dan sistem pengagihan tidak hanya memerlukan kuasa aktif tetapi ia juga memerlukan kuasa kemagnetan untuk beban induktif di bahagian pengguna. Ia adalah penting bahawa stesen janakuasa menghasilkan kuasa aktif dan reaktif. Untuk membekal dan menghasilkan kuasa reaktif, kapasitor pirau digunakan secara meluas. Terdapat beberapa manfaat daripada pemasangan kapasitor pirau dalam sistem pengagihan seperti pampasan kuasa reaktif, pembetulan faktor kuasa, kapasiti sistem , sokongan kuasa, pengurangan kerugian dan peningkatan voltan. Dalam kajian ini, penempatan kapasitor pirau dan saiz kapasitor optimum akan dijalankan. Hasilnya kemudian akan dibandingkan dengan teknik lain dalam bentuk penjimatan kos pemasangan kapasitor. Dalam kajian ini, pengurangan kerugian dan peningkatan profil voltan dikaji. Ia menunjukkan bahawa hampir 14% daripada kerugian disumbangkan di dalam sistem pengagihan. Ia juga amat penting untuk menentukan lokasi yang sesuai kapasitor dalam usaha untuk mengurangkan kehilangan sistem kuasa dan jumlah kos kapasitor. Dalam kajian ini, objektif utama ialah untuk mencari penempatan optimum kapasitor menggunakan pendekatan baru,iaitu Harmoni Search Algorithm di sistem pengagihan yang kemudian digunakan untuk mengurangkan kehilangan kuasa dan meningkatkan profil voltan sistem. Backward/ forward sweep power flow digunakan untuk menentukan aliran kuasa dalam sistem. Prestasi Algoritma yang dicadangkan itu diuji menggunakan 9 bas sistem dan dibandingkan dengan pendekatan lain, iaitu Particle Swarm Optimization.

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LIST OF SYMBOLS

P	-	Real Power
Q	-	Reactive Power
V	-	Voltage
δ	-	Angle
ΔP	-	Change in Active Power Injection
ΔQ	-	Change in Reactive Power Injection
Δδ	-	Change in Angle
ΔV	-	Change in Voltage
J	-	Load Flow Jacobian Matrix
Jx, Jρ	-	Jacobian Matrix of vector function *f*
θ	-	Vector of Bus Voltage Angle
k	-	Vector represents percent load change at each bus
S_i^{sch}	-	The schedule complex power at bus *i*
V_i^k	-	The i^{th} bus voltage at the k^{th} interation.
Q_{ci}	-	Reactive power injections of the shunt capacitor at bus
I_i^k	-	Bus current injection
V_0	-	The initial bus voltage vector
Bi	-	The magnitude of i^{th} branch current.
Ri	-	The i^{th} branch resistance
X_c^h	-	Frequency-dependant
Vk	-	Nominal voltage
H	-	Harmonic order
Qc	-	Capacitor reactive power injection.
gn	-	Generation number
bw(gn)	-	Bandwidth for each generation

bwmin	-	Minimum bandwidth
bwmax	-	Maximum bandwidth.
Nb	-	The number of branch in RDS
h_0	-	The smallest harmonic order of interest
H_{max}	-	The highest harmonic order
Kp	-	The equivalent annual cost per unit of the real power loss ($/kW/year)
Kci	-	The annual cost per unit of the reactive power injection at bus *i* ($/kVar/year)
Qci	-	The reactive power injection at bus *i*(kVar)
Nc	-	The total number if shunt capacitor to be installed
Ploss	-	The total real power loss (kW)
x	-	Vector of state variables
u	-	Vector of control variables.
Q_T	-	Total reactive power
PARmin	-	Minimum pitch adjusting rate
PARmax	-	Maximum pitch adjusting rate
Vmin	-	Lower limit of bus voltage
Vmax	-	Upper limit of bus voltage
|Vi|	-	Rms value of the ith bus voltage which is define as:
Xi	-	Set of possible range of value for each decision
Lxi	-	Lower bound for each decision variable
Uxi	-	Upper bound for each decision variable
bw	-	Arbitrary distance bandwidth for continuous design variable

LIST OF ABBREVIATIONS

BIBC	-	Bus Current and Branch Currents
BCBV	-	Brach currents and Bus Voltage
DLF	-	Matrix between voltage drops and bus current injections
PSO	-	Particle Swarm Optimization
HS	-	Harmony Search
HMCR	-	Harmony Memory Considering rate
RDPF	-	Radial Distribution Power Flow
X/R	-	Ratio between resistance and reactance
PAR	-	Pitch adjusting rate for each generation
NI	-	Number of solution vector generations
IHS	-	Improve Harmonic Search

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CHAPTER 1

1. INTRODUCTION

1.1 Background

Voltage stability is very important in modern power system when utility operate their system at higher and higher load. As the result, it will increase the active and reactive power loss in the system. Study has shown that almost 13% of loses in the system are cause at distribution system an increase in active power, it represent by loss in saving while increase in reactive power loss, it would cause system voltage to drop. Instability may arise from the heavily loaded distribution system.

Now days, capacitor bank are used in distribution system to reduce the active and reactive power loss, increase feeder function as well as it would allow more loads to be install at the respective feeder. Along with voltage drop and power losses, the increase in electricity demand which require upgrading the infrastructure of the distribution system. Shunt capacitor can be of great help to improve or upgrading the infrastructure. The other main advantage that can archive from the capacitor allocation summarized as below:

a) Transmission and Transformation kVA capacity release

b) Overall system peak-load reduction

c) Annual system energy losses reduction.

Distribution system are inherently unbalance for several reason. One of the reasons is cause by single and three-phase loads supply scheme. Secondly, the phases of the transmission line are unequally loaded. Harmony Search Algorithm (HSA) has been proven to handle the optimization problem of any complexity.

1.2 Objectives

This research aims are;

a) To review and identified the optimization technique for optimal capacitor placement in radial distribution system.

b) To find the optimal capacitor placement using Harmony Search Algorithm.

c) To compare the result/performance of Harmony Search Algorithm with Particle Swarm Optimization technique..

1.3 Scope

The scopes of this Project were categorized as below:

a) Identified the several meta-heuristic techniques for optimal capacitor placement in radial distribution system.

b) Calculate the load flow using backward/forward sweep power flow to employed power flow simulations. .

c) Compare the performance /result Improved Harmony Search Algorithm with Particle Swarm Optimization (PSO) technique.

1.4 Report Outline

Chapter 1 address the motivation of this thesis, challenges, its objective encountered to achieve the goal of this study. Chapter 2 will be review area covered by this study. The heuristic method, capacitor placement and sizing problem, and power flow algorithm (RDPF) adopted in this report are also covered in this chapter. In addition, the advantages of Harmony Search Algorithm over the Particle Swarm Optimization (PSO) are reported in this chapter. The system components such as load model, transmission model, capacitor model are cover in Chapter 3. In Chapter 4, it discussed more on the implementation and problem solution develop in this works. The result of the simulation and programming are then discussed more in Chapter 5. The recommendation and future works proposed are explained throughout Chapter 6.

REFERENCES

1. Tinney,W.F ,"Power flow solution by Newton's method, " *IEEE Transaction on Power Apparatus and Systems"*, vol PAS-86, no 11, pp. 1449-1460, 1967

2. Thukaram, D., Wijekoon Banda, H.M and Jerome, J. , "*A robust three-phase power flow algorithm for radial distribution systems*, "Electric Power System Research,vol 50, no 3,pp 227-236,1999.

3. Teng, J.H., " *A modified Gauss-Seidel algorithm of the three-phase power flow analysis in distribution networks*" International Journal of Electrical Power and Energy Systems, vol 24, pp 97-102,2002.

4. Arrillaga,J. , Bradley ,D.A and Bodger, P.S , *Power System Harmonics* , 1st Edition . Wiley, 1985.

5. Kang Seok Lee & Zong Woo Geem "A *new meta-heuristic algorithm for continuous engineering optimization:harmony search theory and practice*" 30 September 2004

6. R.Sirjani, A.Mohamed & H.Shareef, "*An Improved Harmony Search Algorithm for Optimal Capacitor Placement in Radial Distribution System*" PEOCO2011, June 2011.

7. M.Mahdavi , M.Fesanghary & E.Damangir "*An improved harmony search Algorithm for solving optimization problems*" Department Mechanical Engineering, Applied Matcs and Computer Science (2007) 1567-1579.

8. A.Kalyuzhny, G.Levitin ,D.Elmakis & H.Ben-Haim , "*System approach to shunt capacitor in radial distribution system*", 29 January 2000.

9. X.Hou & P.Ju,"*Deterministic & Probabilistic Analysis of Static Voltage Stability in Power System*" IEEE, pp 1-6, 2009, .

10. Cheng Hong Gu, Qian Ai & Jiayi Wu," *A Study of Effect of Different Static Load Model and System Operating Constraints on Static Voltage Stability*", 5th WSEAS,2005.

11. Young Hyun Moon, Heon Su Ryu, Jong Gi Lee & Baik Kim, " *Uniqueness of Static Voltage Stability Analysis in Power System*", IEEE, pp 1536-1541 vol.3 ,2001.

12. Thomas J.Overbye*,"Power System Simulation:Understanding small and large system operation",* IEEE Power & Energy, Vol.2 No.1,2004.

13. Yakout Mansour & Claudio Canizares*,"Voltage Stability",* Taylor & Francis Group, 2006.

14. Young Huei Hong, Ching Tsai Pan & Wei Wen Lin, " *Fast Calculation of A Voltage Stability Index of Power System*", IEEE Vol.12 No.4, Nov 1997.

15. Ali Zare & Ahad Kazemi,"*Proposing a novel method for analyzing static voltage stability"*, WSEAS, May 2008.

16. Hadi Saadat, "*Power System Analysis*",2nd Edition,2002 Mc Graw-Hill.

17. A. Venkataramana, " Computational Techniques for Voltage Stability Assessment and Control".