Faculty of Electrical Engineering

OPTIMAL ALLOCATION AND SIZING OF CAPACITOR BANK AND DISTRIBUTED GENERATION USING PARTICLE SWARM OPTIMIZATION

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DECLARATION

I declare that this thesis entitled "Load Forecasting and Optimal Allocation & Sizing of Capacitor and Distributed Generation of Power Systems Using Particle Swarm" is the result of my own research except the one cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

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Date : ....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature	:	…………………………………
Supervisor Name	:	Professor Ir. Dr. Marizan bin Sulaiman
Date	:	…………………………………

DEDICATION

I would like to dedicate my thesis work to my family, relatives, and friends

ABSTRACT

Power systems are complicated to be solved due to vast geographical location and are influenced by many unexpected weather events. The rapidly increasing population growth and the expansion of urban development are undoubtedly the main reasons for increasing electrical power demands that may affect the system voltage stability and the energy loss. Accurate long-term load forecasting (LTLF) is essential for load demand requirements. It is particularly significant under the influence of various weather factors, such as relative humidity and temperature. The research work presented in this thesis had investigated the effect of two additional weather parameters, namely wind speed and rainfall, in addition to the temperature and relative humidity using artificial neural network (ANN) and adaptive neuro-fuzzy inference system (ANFIS) in predicting the values of load demands. Moreover, the optimal allocation and sizing of the capacitor bank (C) and distributed generation (DG) were studied with the particle swarm optimization (PSO) technique to maintain the profile of bus voltages while reducing the energy loss of the network. This technique was also applied to the load incremental of 5% annually up to 40% for system planning purposes. As for the LTLF, ANFIS produced better results than ANN; and with two additional parameters of wind speed and rainfall, it delivered a more accurate prediction. The PSO algorithm allocates and determines the size of the capacitor and distributed generation in the power system. The capacitors and distributed generation are compensators that helped the power system network improve the voltage profile and reduce power loss. The proposed PSO algorithm was used with the OpenDSS engine to solve the power flow through the MATLAB and has been successful implemented in finding an optimal allocation and suitable size of the capacitor and distributed generation. In order to validate the functionality of the proposed PSO algorithm, the IEEE 14–bus and 30–bus systems were used as test systems. The research evidently indicated the PSO algorithm can be applied to the power system planning analysis for the placement and sizing of the capacitor and distributed generation while maintaining the acceptable voltage profile and minimizing the power loss.

PERUNTUKAN DAN PENSAIZAN OPTIMUM BANK KAPASITOR DAN PENJANAAN TERAGIH MENGGUNAKAN PENGOPTIMUMAN PENGUMPULAN ZARAH

ABSTRAK

Sistem kuasa adalah rumit untuk diselesaikan kerana melibatkan lokasi geografi yang luas dan dipengaruhi oleh keadaan cuaca yang tidak dijangka. Pertumbuhan populasi penduduk dan pembangunan bandar yang pesat tidak diragukan lagi menjadi punca utama peningkatan permintaan tenaga elektrik yang mungkin mempengaruhi kestabilan voltan sistem dan kehilangan tenaga. Peramalan beban jangka panjang (LTLF) yang tepat adalah sangat penting bagi memenuhi keperluan permintaan beban. Ia sangat ketara di bawah pengaruh pelbagai faktor cuaca, seperti f kelembapan relatif dan suhu. Kerja penyelidikan yang dikemukakan dalam tesis ini telah mengkaji pengaruh dua parameter cuaca tambahan iaitu kelajuan angin dan hujan, sebagai tambahan kepada faktor suhu dan kelembapan relatif dengan menggunakan rangkaian neural buatan (ANN) dan adaptive neuro-fuzzy inference system (ANFIS) dalam meramalkan nilai permintaan beban. Tambahan pula, penempatan optimum dan pensaizan bank kapasitor (C) dan penjanaan teragih (DG) dikaji dengan teknik pengoptimuman pengumpulan zarah (PSO) untuk mengekalkan profil voltan-voltan bas di samping mengurangkan kehilangan tenaga dalam rangkaian. Teknik ini juga telah diterapkan pada kenaikan beban 5% setiap tahun hingga 40% bagi tujuan perancangan sistem. Bagi LTLF, ANFIS menghasilkan keputusan yang lebih baik berbanding ANN; dan dengan dua parameter tambahan iaitu kelajuan angin dan hujan, ia memberikan ramalan yang lebih tepat. Algoritma PSO menempatkan dan menentukan saiz kapasitor dan penjanaan teragih dalam sistem kuasa. Kapasitor dan penjanaan teragih adalah pemampas yang membantu rangkaian sistem kuasa meningkatkan profil voltan dan mengurangkan kehilangan kuasa. Algoritma PSO yang dicadangkan telah digunakan dengan OpenDSS untuk menyelesaikan masalah aliran kuasa melalui MATLAB, dan ia telah berjaya dilaksanakan dalam pencarian penempatan optimum dan saiz kapasitor dan penjanaan teragih yang sesuai. Untuk mengesahkan fungsi algoritma PSO yang dicadangkan, sistem bas IEEE–14 dan sistem bas IEEE–30 telah digunakan sebagai sistem ujian. Penyelidikan ini membuktikan bahawa algoritma PSO dapat diaplikasikan untuk analisis perancangan sistem kuasa bagi penempatan dan pensaizan kapasitor dan DG sambil mengekalkan profil voltan yang dapat diterima dan meminimumkan kehilangan kuasa.

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Ai	-	Linguistic label associated with node i
c1, c2	-	Weighting factor
c_l	-	Total capacitor
$F_f(v_k)$	-	Activation function
G^{best}	-	Global best of the group
NTD	-	Total number of training data
P	-	Real power
PU	-	Per unit
P^i_{Loos}	-	Power losses at bus *i*
PV	-	Real power - voltage
PF	-	Penalty factor
p^{best}_i	-	Personal best of particle *i*
Q	-	Reactive power
R	-	Rainfall
r_1, r_2	-	Random numbers between 0 and 1
T	-	Time
T°C	-	Temperature
v_1^k	-	Current velocity of particle ι at iteration κ
V_1^{k+1}	-	Modified velocity of particle ι

W	-	Wind speed
γ	-	Voltage violation coefficient
ω	-	Weighting function
$\propto$&β	-	Acceleration coefficient
$\mu_{\underline{Ai}}$	-	Membership function associated with Ai

LIST OF ABBREVIATIONS

AC	-	Alternating Current
AI	-	Artificial Intelligence
AR	-	Autoregressive
ANN	-	Artificial Neural Network
ANFIS	-	Adaptive Neuro - Fuzzy Inference System
ANN-BP	-	Artificial Neural Network - Back Propagation
ACO	-	Ant Colony Optimization
DC	-	Direct Current
DSO	-	Distribution System Operator
DG	-	Distributed Generation
FL	-	Fuzzy Logic
FLC	-	Fuzzy Logic Control
FLS	-	Fuzzy Logic System
GOS	-	Global Optimum Solution
GA	-	Genetic Algorithm
H	-	Humidity
IEEE	-	Institute of Electrical and Electronics Engineers
LTLF	-	Long-Term Load Forecast
MTLF	-	Medium-Term Load Forecast

MLBP	-	Multilayer Perceptron with Back Propagation
MF	-	Membership Function
MV	-	Medium Voltage
MAPE	-	Mean Absolute Percentage Error
OF	-	Objective Function
OpenDSS	-	Open Source Distribution System Simulation
PSO	-	Particle Swarm Optimization
SA	-	Simulated Annealing
STLF	-	Short-Term Load Forecast
TS	-	Tabu Search

LIST OF PUBLICATIONS

Journals:

1. Eltawil, N.A, Sulaiman, M., Shamshiri, M., and Ibrahim, Z., 2019. Optimum Allocation of Capacitor and DG in MV Distribution Network Using PSO and Open DSS. *Asian Research Publishing Network (ARPN) Journal of Engineering and Applied Sciences*, 14(2), pp. 363-371. (SCOPUS)
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CHAPTER 1

INTRODUCTION

1.1 Background

Power systems are complex in terms of the geographical aspects and widespread, thus, it is complicated to address the power system problems. They are affected by various unanticipated incidents. The long – term load forecasting (LTLF), medium-term load forecast (MTLF), short-term load forecast (STLF), and very short-term load forecast (VSTLF) are the categories for load forecasting. The LTLF is a system that predicts load with a lead time of more than one year. The MLTF, on the other hand, is a system that predicts load with a lead time from a week to a year. Meanwhile, the STLF is a system that predicts load with a lead time of between an hour and a week. The fourth predicting load system is the VSTLF that has a lead time from one minute to an hour.

The main objective of the LTLF is for the power system expansion to predict the effect of weather parameters such as temperature, humidity, rainfall and wind speed on the load forecasting. These parameters must be taken into account the demand load growth to improve distribution facilities, economic planning, infrastructure, technological developments and, utilities and accuracy in load forecasting are both significant in analysing load characteristics (Al-Hamadi, 2011; Swaroop an Al Abdulqader, 2012). Some effects of weather parameters must take into account the accuracy of different types of load forecasting, which leads to ill-suited data selection and decline accuracy in poor data analysis. Several issues should be considered for the medium-term load forecast, for instance, the development of power system infrastructure, tariff, and purchase agreements,