MULTIPLE-ARM PASSIVE FILTERS DESIGN BASED ON DIFFERENT REACTIVE POWER DIVISION APPROACHES

By

Sameh Sayed Kandil Ibrahim

A thesis submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
In
Electrical Power and Machines Engineering

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Title of Thesis:

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Keywords:

Harmonic distortion, Passive filters, Power factor, Power quality, Crow Search Algorithm.

Summary:
This thesis introduces a comparative study of different techniques for reactive power division among shunt passive filter arms. A new optimization algorithm which is known as Crow Search Algorithm (CSA) is applied for 5th, 7th, and 11th harmonic filters design to achieve the parameters that can present the minimum current total harmonic distortion. The investigated test system is simulated using ETAP and Matlab environments, and then an equivalent model is constructed for the case study using Matlab-Simulink for validation purposes. The comparison criteria include network performance indices like harmonic distortion levels, filtering characteristics of the different design techniques, filter effectiveness, harmonic amplification ratio, and the risk of filters outage on the distortion levels. The filtering cost was evaluated to check the most economical technique. Finally, the filters' duties were checked according to the international standards to ensure a safe operation of filters.

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DEDICATION

TO MY MOTHER, MY SOURCE OF INSPIRATION.

TO SPIRITS OF THE MARTYRS: ENG. MOHAMED REDA AND ENG. MOHAB SALEH.

TO SPIRITS OF THE MARTYRS OF FACULTY OF ENGINEERING – CAIRO UNIVERSITY.

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LIST OF ABBREVIATIONS

PCC	Point of Common Coupling
THDI	Total Harmonic Current Distortion
THDV	Total Harmonic Voltage Distortion
IHD	Individual Harmonic Distortion
HAR	Harmonic Amplification Ratio
PF	Power Factor
CSA	Crow Search Algorithm
NSGA	Non-Dominated Sorting Genetic Algorithm
VSD	Variable Frequency Drive
ASD	Adjustable Speed Drive
OF	Objective Function
FL	Flight Length
AP	Awareness Probability
BA	Bat algorithm
PSO	Particle swarm optimization
SA	Simulated annealing

LIST OF SYMBOLS

I_f , I_1	RMS value of the fundamental current
I_h	RMS value of the harmonic current
Q_C	total three phase reactive power supplied by the capacitor bank
P	total three phase active power
S	total three phase apparent power
Cos Φ	load power factor
R	internal resistance of the inductor
L_f	inductance of the filter inductor
C_f	capacitance of the filter capacitor
F_0	resonant frequency
Q	reactive power supplied by the filter branch
X_L	inductive reactance of the filter
X_C	capacitive reactance of the filter
q	quality factor of the reactor
H	harmonic order
N	Number of filter arms
Q_{ith}	three phase reactive power supplied by the ith filter
IHD_{ith}	Individual harmonic distortion of the ith order.
IHD_{max}	maximum allowable individual harmonic distortion
$THDI_{max}$	maximum allowable total harmonic current distortion
$THDV_{max}$	maximum allowable total harmonic voltage distortion
Tanδ	loss tangent of the capacitor
Θith	phase shift of the ith waveform
ω_1	fundamental angular frequency
C_{ith}	capacitance of the ith filter capacitor

V_1	RMS value of the fundamental phase voltage
I_{ith}	RMS value of the ith harmonic current
V_{ith}	phase voltage across the ith capacitor
$P_{\delta ith}$	specific power losses of the ith filter branch
ω_p	angular frequency of the parallel resonance
F_C	capacitor power losses
K_{CL}	loss factor of the capacitor
P_h	present value factor
i	interest rate
F_U	filter utilization factor
U_U	cost of the power losses
U_C	incremental cost of the capacitor
U_L	incremental cost of the reactor
I_{SC}	RMS value of the short circuit current
I_L	RMS value of the load current
R_{SC}	short circuit resistance
X_{SC}	short circuit inductive reactance
$V_f(h\omega)$	harmonic voltage percentage after filter installation
x (i,t)	position function of the crow i at iteration t
m(i,t)	memory function of the crow i at iteration t
r_i	probability function with uniform distribution
fl (i,t)	flight length function of the crow i at iteration t
V_{rated}	rated voltage across the capacitor
I_{rated}	rated current through the filter
Q_{rated}	rated reactive power of the filter
V_C	RMS value of the voltage across the capacitor

I_C	RMS value of the current flowing through the filter
Q_C	RMS value of the filter reactive power
X_{C1}	fundamental capacitive reactance
Z_{fh}	filter impedance at the harmonic order h
h_{max}	maximum harmonic order
$Q_{desired}$	required reactive power of the compensation
x	Fixed cost (investment) of the filter
y	Power losses cost (operating) of the filter
δ	Filter tuning factor