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Loss minimization techniques used in distribution network: bibliographical survey

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ABSTRACT

Distribution system provides a link between the high voltage transmission system and low voltage consumers thus I^2R loss in a distributed system is high because of low voltage and high current. Distribution companies (DISCOs) have an economic enticement to reduce losses in their networks. Usually, this enticement is the cost difference between real and standard losses. Therefore, if real losses are higher than the standard ones, the DISCOs are economically penalized or if the opposite happens, they obtain a profit. Thus loss minimization problem is a well researched topic and all previous approaches vary from each other by selection of tool for loss minimization and thereafter either in their problem formulation or problem solution methods employed. Many methods of loss reduction exist like feeder reconfiguration, capacitor placement, high voltage distribution system, conductor grading, Distributed Generator (DG) Allocation etc. This paper gives a bibliographical survey, general background and comparative analysis of three most commonly used techniques (i) Capacitor Placement, (ii) Feeder Reconfiguration, (iii) and DG Allocation for loss minimization in distribution network based on over *147* published articles, so that new researchers can easily find literature particularly in this area.

Contents

1. Introduction

Losses in transmission and distribution networks represent the single largest consumption in any power system. Due to the rapid increase in the demand for electricity, environmental constraints and competitive energy market scenario the transmission and distribution systems are often being operated under heavily loaded conditions and the distribution system loss has become more and more of a concern. The requirement to provide acceptable power quality and enhanced efficiency to achieve all possible economic benefits will create a very favorable climate for the need of loss minimization techniques and innovative operating practices. The total power delivered to the distribution system has been calculated according to the total power generation and power loss of the transmission system. To enhance the efficiency

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Nomenclature

L	energy loss caused by quadrature current in feeder
CkVA	capacitive kilovolt-amperes
KVAr	reactive kilovolt-amperes
kVA	kilo volt-amp
RMS	root mean square
EP	evolutionary programming
ULTC	under-load tap changer
CL	capacitor location, per unit (pu) of total feeder resistance
CR	rated capacitor current, pu of maximum input quadrature current to feeder
$T1, T2\ldots Tn$	time, pu of period of load cycle, during which the input quadrature current equals
$X1, X2, \ldots Xn$	ratio between input quadrature current during time Tn and maximum input quadrature current
R	line resistance in pu
i	reactive current at feeder
X	distance from feeder
LE	energy loss
x	distance measured along the normalized equivalent uniform feeder
$F(x)$	feeder reactive current function
z	control variable
DPSO	discrete particle swarm optimization
I_S	peak reactive current injected into the feeder
r	P.U. length resistance of line
I_{cj}	sizes of shunt capacitors (i=1,2……n)
t	time required to on/off fixed capacitors
OF	objective function ($)
OD	present worth of revenue requirements of one dollar investment, ($/$)
BPSO	binary particle swarm optimization
RC	cost of released kVA capacity ($)
CC	construction cost of all related capacitor installations ($)
τ	power loss reduction time
SC	annual marginal cost of system capacity ($/kW)
PL	power loss savings at time of system peak (kW)
EC	marginal cost of energy losses ($/kWh)
EL	annual energy loss savings (kWh)
Fp, F_E	present worth factors for power and energy losses, which are functions of discount rate, comparison time interval and appropriate cost escalation.
X_{line}	aggregate reactance of the line connecting the load to the feeding substation
$S_{\text{Loss }ij}$	power loss in line i–j
S_{ij}	complex power from bus i to j
S_ji	complex power from bus j to i
$P_q(\tau)$	power loss reduction at time τ
I_c	capacitor current
$a(\tau)$	the substation load time variation
H	matrix to calculate distance between substation to capacitor
bT	reactive load current distribution
I_2	end load current
S	savings ($/yr)
LP	reduction in peak power losses
CC	total cost of capacitors
Kp	factor to convert peak power losses to dollars
Ke	factor to convert energy losses to dollars
δ	load angles
θ	voltage angle
m, q	variables to represent number of buses
F	objective function
Kr	annual cost per unit of the real power loss ($/kW/yr)
P_{load}	active power of load
Q_{load}	reactive power of load
TPC	Taiwan power company
Kc	annual cost per unit of the reactive power injection at bus i ($/kVAR/yr)
Qc	reactive power injection at respective bus
P_B, Q_B	active and reactive power flow in the branch
P_L, Q_L	active and reactive load power
Q_C	capacitor power
CPU	central processing unit
R	resistance of branch
J	complex current flow in branch
Em	component of' $E=R_{\text{bus}}I_{\text{bus}}$' corresponding to bus m. R_{bus} is the "bus resistance matrix" of feeder before the load transfer which is found using the substation bus as reference.
I_{bus}	the vector of bus currents for feeder
En	similar to Em, but defined for bus n of next Feeder.
P_{DG}	active power of DG
Re	real part of impedance.
V_L	load voltage
P_{rloss}	real power loss of the system.
kp, ke and kq	the cost of power loss at peak-load time (in $/kW), the cost of fuel served for energy losses (in $/kWh) and the cost of reactive sources (in $/kVAr), resp.
τa	fraction of time in load curve
Q_{DG}	reactive power of DG
SCADA	supervisory control and data acquisition

of distribution system loss minimization is the only alternative. Thus it is found that, since last three decades research in distribution systems has been focused on line loss minimization and voltage regulation. Various methods of loss minimization in distribution system are available in the literature but the basic three methods such as (i) Capacitor Placement (generally applicable in high voltage distribution systems) (ii) Feeder Reconfiguration (generally applicable in low voltage distribution systems) and (iii) DG Allocation (more focused to achieve interconnection when small generators exists. For instance, when isolated wind farms or small photovoltaic plants enter the distribution network) are discussed here.

Traditionally, loss minimization has focused on optimizing network reconfiguration or reactive power support through capacitor placement. However, the evolution from passive distribution networks to active due to the insertion of DG presents opportunities. Although planning issues, the regulatory framework and the availability of resources limit Distribution Network Operators (DNOs) and developers in their ability to accommodate distributed generation, governments are incentivizing low-carbon technologies, as a means of meeting environmental targets and increasing energy security. This momentum can be harnessed by DNOs to bring network operational benefits through lower losses delivered by investment in DG [1]. This article incorporates the various approaches made by researchers in order to minimize the

distribution losses and the prolonged study shows that the loss minimization by DG allocation is providing enhanced prospects.