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Geographic information system and weather based dynamic line rating for generation scheduling

Ram Jethmalani C. Hemparuva [a,*], Sishaj P. Simon [b], Sundareswaran Kinattingal [b], Narayana Prasad Padhy [c]

[a] Department of EEE, National Institute of Technology, Puducherry, India
[b] Department of EEE, National Institute of Technology, Tiruchirappalli, India
[c] Department of Electrical Engineering, Indian Institute of Technology, Roorkee, India

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ABSTRACT

Transmission line ratings influence the economic and security aspects of power system operation, generation and planning. The use of geographical information systems in power system generation and planning activities is gaining importance. This paper proposes a geographical information system and weather based dynamic line rating (GISWDLR) and investigates its effectiveness in a security constrained unit commitment problem (SCUCP). Here, the dynamic line ratings (DLRs) of conductors at different locations along the transmission line are calculated using the geographic parameters and weather parameters. Thereafter, the minimum value of DLRs at all indentified locations of the transmission line is taken as DLR of the transmission line. Here, binary real coded particle swarm optimization (BRPSO) is employed to solve the SCUCP. The proposed method is validated using the benchmark IEEE 30 bus system. Here, results obtained using the proposed GISWDLR, static line rating (SLR) and conventional UCP are compared. Also, the effectiveness of BRPSO is validated by comparing it with the conventional enhanced priority list based method.

1. Introduction

In a restructured power system, the independent system operator (ISO) dispatch centre prepares the schedule for the next day by solving scheduling problems such as security constrained unit commitment problem (SCUCP) or profit based unit commitment problem (PBUCP). In restructured markets, including the PJM interconnection, the New York market, and the U.K. Power Pool, the ISO plans the day-ahead schedule using security-constrained unit commitment. Here, the ISO collects detailed information on each generating unit including characteristics such as start-up costs, minimum up time and minimum down time, minimum and maximum unit outputs, and bids representing incremental heat rate from the generation companies (GENCOs). The ISO also obtains information from transmission companies (TRANSCOs) on transmission line capability and availability. Then, the ISO uses the SCUC model to determine the optimal allocation of generation resources [1]. The power transfer limit of transmission lines is an important constraint for solving the power system scheduling problem (PSSPs). This constraint plays an essential role in the secure and economic management of the power system [2,3]. The available transmission line capacity is calculated using the value of maximum power transfer limit. Therefore, considering the above process, the objective of this article is to improve the solution quality of SCUCP, in which dynamic transmission line ratings are considered.

A geographic information system (GIS) is designed to work with data referenced by spatial or geographic coordinates [4]. The smart grid aims to integrate information systems into existing power systems [5]. GIS is used as a tool to enable effective power system functions such as network planning, outage response, asset management, by the power utilities [6,7]. GIS along with the weather parameters are used in this article to calculate transmission line ratings. These transmission line ratings are used to solve the PSSPs. Ampacity of a transmission line is the maximum current it can carry without either reducing the tensile strength or exceeding the maximum permitted sag [8]. This current limit is translated into power transmission limit. Traditionally, thermal ratings are calculated seasonally assuming given conservative weather condi-

* Corresponding author at: Department of EEE, National Institute of Technology, Puducherry, India.
E-mail address: malanisuryakumaran@gmail.com (R.J.C. Hemparuva).

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Nomenclature

Parameters, functions and variables

B	Susceptance of transmission line
$CLOL$	Cumulative loss of load
C_1	Cognitive scaling factor
C_2	Social scaling factor
FC	Fuel cost
$FitB$	Fitness of binary string.
$FitR$	Fitness of a real string used in solving OPF.
G	Conductance of transmission line
Gb	Global best position
H_e	Conductor elevation from sea level
I_i^t	ON/OFF status of generating station '*i*' and schedule interval '*t*'
K	Spinning reserve requirement
L_t	Latitude of location
L_n	Longitude of location
$MOVI$	Minimum ON/OFF violation index
N	Day number in a year
N_{bp}	Number of binary coded particles
N_{rp}	Number of real coded particles
nc	Number of shunt capacitor banks
ng	Number of generators
nl	Number of transmission lines
OC	Operational cost
Pb	Particle best position
PT_{Loc}^{max}	Maximum power transfer limit at a location
PT_{Line}^{max}	Maximum power transfer limit of a transmission line
$P_{i,t}$	Power generated by generator '*i*' in interval '*t*'
$P_{Di,t}$	Power demand at bus '*i*' in interval '*t*'
PRM	Real power mismatch in percentage
PQM	Reactive power mismatch in percentage
q_c	Heat dissipated by a conductor through convection
QI	Reactive power injection
QD	Reactive power demand
q_s	Solar heat gain
$QG_{i,t}$	Reactive power generated by generator '*i*' in interval '*t*'
$QGLV$	Reactive power limit violation index
QM	Reactive power balance mismatch
RM	Real power balance mismatch
SD_i^t	Shut down cost of generator '*i*' in interval '*t*'
SU_i^t	Startup cost of generator '*i*' in interval '*t*'
SI	Severity index
T	Number of schedule intervals
T_a	Ambient temperature
$T_{i,t}^{ON}$	Minimum up-time of generator '*i*'
$T_{i,t}^{OFF}$	Maximum up-time of generator '*i*'
Rd_i	Ramp up limit of generator '*i*'
Rp_i	Ramp down limit of generator '*i*'
$V_{i,t}$	Magnitude of voltage at bus 'i' in interval '*t*'
Vl	Velocity of best particle
w_d	Wind direction
w_s	Wind speed
X_I	Binary PSO particle representing ON/OFF status
$X_{i,t}^{ON}$	'ON' duration of generator '*i*' till interval 't'
$X_{i,t}^{OFF}$	'OFF' duration of generator '*i*' till interval '*t*'
z_l	Azimuth angle of transmission line
ρ_f	Density of air surrounding the conductor
W	Inertia

Parameters, functions and variables

i	Generator index
I	Particle index
k	Iteration count
t	Time interval index

tions. These static line ratings (SLR) mostly lead to conservative operational limits. Also, SLRs are over estimated at extreme weather conditions as they ignore the impact of weather on the line capacity [9]. DLR is also a useful approach to provide temporary additional transmission capacity while ensuring the power system security with higher loading of transmission lines [3].

If most of the economic units are located in one region of the system, it becomes more difficult to satisfy network constraints throughout the system. As the network becomes more congested, the system operator should incorporate the network flow constraints in the PSSP to minimize the violation and the related costs of the normal operation of the system [10]. The maximum power transferred (PT^{max}) by a conductor depends on temperature of the transmission line. The temperature of the transmission line is influenced by the following factors [11]:

1. Ambient weather conditions such as the wind speed, wind direction, solar radiation and precipitation.
2. The geographic orientation of conductor such as the line direction and line height.
3. Specification of the conductor including conductor size, resistance, sag and the type of conductor surface.
4. Current flowing through the conductor.

The models to obtain temperature and current of a transmission line are discussed in IEEE 738 guidelines [11]. Methods to determine the power transmission limit is categorised as follows [12,13]:

1. Weather forecast based systems
2. Temperature measurement based systems
3. Sag monitoring based systems

In [14], a DLR forecast system using probabilistic approach is proposed. Here, the historical data of weather and power transmitted are used. In [15], DLR values are obtained using weather parameters and conductor temperature monitoring system. In [16], sag of transmission lines are measured using tension monitoring systems. Here, tension monitors are installed between dead-end insulators and the dead-end structure of the transmission lines. The tension measured using the monitors are used to calculate sag of the transmission line, which is used to calculate the transmission line rating of the transmission line. In [17], DLR of transmission lines are calculated using temperature sensors placed on the transmission lines. In [18], expert systems are used to predict DLR of transmission lines. In [19], a linear model to calculate DLR based on meteorological data is presented. In [20], weather prediction models are used along with machine learning algorithms are used to predict DLR of transmission lines. In [21], major considerations in selection of DLR various DLR systems are discussed. In [22] the increased use of weather forecast on predicting DLR is discussed. In [23], different line rating forecasting methods are compared. The commercially available DLR monitoring systems along with short description on the operation principle is given in Table 1.

In [9], the effect of DLR on economic dispatch of generators with wind power integration is investigated. Also, the use of DLR in