A Decentralized Optimization for Risk Based Regional Congestion Management

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ABSTRACT

A new decentralized risk-based congestion management method is proposed, in which the object function is represented by utility value in electricity market. Centralized optimization approaches are primarily employed in congestion management study , however, decentralized optimizations are used to make decisions in real regional markets. In this paper, participants in different regions are allowed to pursue their own profits and utility functions are defined to synthesize the profit and the congestion risk. The system operator with more priority coordinates the relations between the decentralized schemes. It is evident that the decentralized scheme is more realistic in regional market management. Congestion management with thermal rating risk assessment will coordinate the security and efficiency of transmission network and obey the rules of market operation. The utility function is based on Optimal Power Flow (OPF) coupled with short-term transmission line thermal overload r1isk assessment. Simulation tests on IEEE 30-bus system demonstrate that the predicted risk of thermal overload is useful for online decision making and the decentralized risk based congestion management approach is transparent and efficient to the market participants.

1. INTRODUCTION

In a competitive market environment, the uncertain and diverse market patterns have greatly increased complexity in power operations and operational planning. To maintain system reliability under uncertainty, studies are performed to aid in operating decisions. The current practice uses deterministic methods with significant Transmission Reliability Margins (TRM) to cover all the possible operation patterns [1].

As the weaknesses in using deterministic method for performing security assessment, this paper motivates and describes an assessment method that called *Decentralized Risk-based Congestion Management* (DRCM). Then, the short-term transmission line thermal overload risk assessment is used in optimal power flow (OPF) to compute generation unit commitment and transmission flow plan. Finally, simulation tests on IEEE 30-bus system testify the value of risk assessment for decision-making.

2. LINE OVERLOADING RISK

The thermal overload risk is the product of the thermal overload probability and its expectation of costs [4]. Given the current I, we may compute thermal overload risk as the probability of the temperature being greater than the maximum design temperature θ_{MDT} , times its related impacts:

$$R(I)=\int_{\theta>\theta_{MDT}}\rho(\theta\,|\,I)\times(I_{sag}(\theta\,|\,I)+I_{anneal}(\theta\,|\,I))d\theta \tag{1}$$

Here θ is the conductor temperature with the ambient conditions and $R(I)$ is the risk regarding the line loading. $\rho(\theta\,|\,I)$, the probability density function θ of given I, is the summation of the joint probability of all ambient conditions $(\underline{z})$ such that the temperature determined by them under the given current I:

$$\rho(\theta\,|\,I)=\sum\nolimits_{\underline{z}}\rho(\underline{z}) \quad \forall\,\underline{z}\in\left\{\underline{z}:\theta(\underline{z},I)=\theta\right\} \tag{2}$$

where,

$$\rho(\underline{z})=\rho(\vartheta\,|\,u)\times\rho(u) \tag{3}$$

$$\begin{aligned}\rho(\theta)&=\frac{1}{\sqrt{2\pi\sigma^2}}\times e^{-\frac{(\theta-\mu)^2}{2\sigma^2}}\\ \rho(u)&=\frac{\gamma}{\beta}u^{\gamma-1}e^{-u^{\gamma}/\beta}\end{aligned} \tag{4}$$

The random behaviors of air temperature θ and wind speed u are modeled as Normal and Weibull distribution respectively, where the optimal parameters of distribution functions can be obtained using point estimation form historical data. If the correlation between θ and u is negligible, then $\rho(\vartheta\,|\,u)=\rho(\vartheta)$ in Eq. (3). Here, μ,σ,γ and β are the scale and shape parameters for both distributions.

3. MATHIMATICAL MODEL

Before further discussion, it is useful to state the underlying assumptions:

- Power flow loss is neglected and direct current power flow model is used. The *Power Transfer Distribution Factor* (PTDF) is fixed.
- All the market participants bid to maximize the profits rationally and independently.
- All the market information can be issued timely from the central servers.

For N_b system nodes and N_l system buses in a market driven environment, the power transmission load flow value under transaction *m* is:

$$z^{(m)}=XA(A^TXA)^{-1}q^{(m)}=Hq^{(m)} \tag{5}$$

where, X = *Nl* * *N*l line reactance diagonal matrix,
A = *Nl*(Nb-1)* correlated node-line matrix without the line of slack node,
$q^{(m)}$ = the injected power vector under transaction *m*,
$z^{(m)}$ = the power transmission load flow value under transaction *m*, and
H = the power transfer distribution factor.

The objective function of decentralized congestion management optimization is:

$$\max_{g^{(m)},d^{(m)}} f^{(m)}=\sum_{i=1}^{N_b}B_i(d_i^{(m)})-\sum_{j=1}^{N_b}C_j(g_j^{(m)})-\phi H^T R(I^{(m)}) \tag{6}$$

$$\text{s.t.} \sum_{i=1}^{N_b} d_i^{(m)} - \sum_{j=1}^{N_b} g_j^{(m)} = 0 \tag{7}$$

$$z_l = I_l U \leq z_l^{max}$$

Here, B_i is the benefit of power consumer d_i and C_j is the cost of power supplier g_j. z_l is the transmission load flow besides the congestion lines. ϕ is the weighting factor.

The optimized function means the maximization of the utility function. It is recognized as the satisfied degree of the utility in valuation of strategies. According to Eq. (6), the optimized utility is improved with the increase of expected benefit and reduced with the increase of the overload risk. ϕ can be modified according to the impact of risk to utility[3].

The distribution congestion management is achieved with the communication and multi-agent techniques. Each agent as one transaction coordination operator receives information from the Internet and calculates the utility function in Eq. (6) in this transaction. The security server has the optimized transaction data from all agents and update the congestion management info in web. The character of DRCM is the independence between different agents ($d^{(m)}, g^{(m)}$). Each transaction coordination operator can seek the optimization of transaction schedule ($d^{(m)}, g^{(m)}$).

4. EXAMPLE

The effect of the utility algorithm in DRCM is illustrated using the classical IEEE-30 bus system [2]. The partition and combination of areas is shown in Fig. 1 and there have been 9 consumers and 6 producers for bidding. The assumed market demand and supply functions are shown in Table 1. Each market group gets all market participants' data, but only optimizes the demands and producers in its own area.

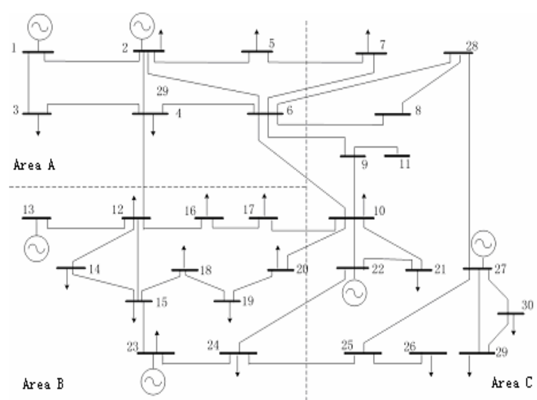

Fig. 1 IEEE 30-bus system

It is supposed that all the generators and loads bid price according to the marginal supply and demand function. With normal optimal power flow calculation, line 6-8 have congestion problem and the node price in load 6-8 is much higher than other node prices.

In DRCM, the line thermal overload risk is firstly calculated. It is known that the parameters of the air temperature and wind speed:

$$\mu = 15^\circ\text{C}, \sigma = 6.3^\circ\text{C}, \gamma = 1\text{m/s}, \beta = 0.4\text{m/s}, \theta_{\text{MDT}} = 100^\circ\text{C}$$

According to Eq. (1), the overload thermal risk values of different current in line 6-8 shows in Fig. 2.

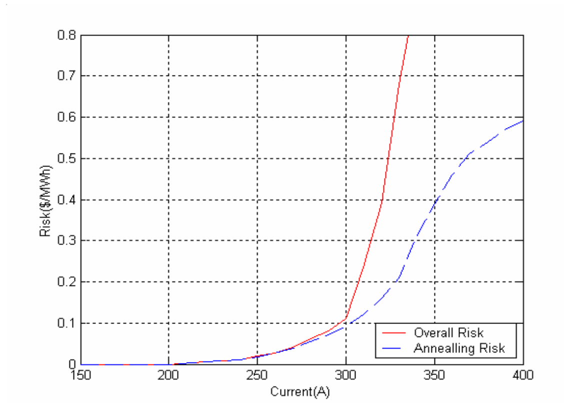

Fig. 2 Risk of different current

Table 1 Assumed market demand and supply functions for the example

Area No.	Genera- tor No.	Supply Function	Load No.	Demand Function
A	1 2	0.02q+2 0.0175q+1.75	3 4 7	3.88-0.03q 3.9-0.05q 3.8-0.02q
B	13 23	0.025q+3 0.025q+3	12 15 17	3.8-0.04q 3.95-0.02q 3.7-0.02q
C	22 27	0.625q+1 0.00834q+3.25	24 26 30	3.6-0.03q 3.8-0.04q 3.7-0.02q

Table 2 Results of decentralized risk-based congestion optimization

Node No.	Optimization in Area A	Optimization in Area B	Optimization in Area C	Sum
1	45.06	0	0	45.06
2	59.53	0	0	59.53
3	1.856	0.171	0.373	2.40
4	5.912	0.537	1.151	7.60
7	16.893	1.882	4.025	22.80
12	8.294	0.928	1.978	11.20
13	0	19.68	0	19.68
15	6.504	0.540	1.156	8.20
17	6.196	0.893	1.911	9.00
22	0	0	23.8	23.80
23	0	19.7	0	19.70
24	5.276	1.108	2.316	8.70
26	2.591	0.291	0.618	3.50
27	0	0	46.57	44.57
30	7.297	1.052	2.251	10.60

With the incorporating analysis of line overload risk, the whole welfare can be maximized to system security operators. Fig. 3 is a comparison to the whole welfare between load power constraints and load risks without power constraints.

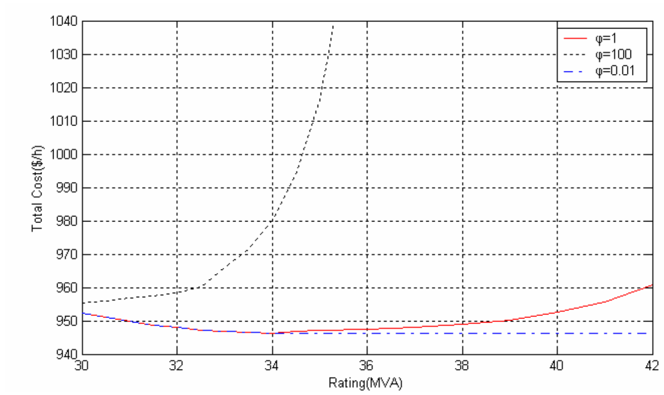

Fig. 3 Total welfare on different rating

5. CONCLUSIONS

A new method for the decentralized solution of risk-based congestion management has been presented. The method consists of the iterative solution of modified OPF sub-problems whose solutions converge to the global OPF solution. The central security coordination is required.

Advances in decentralized OPF solution will greatly facilitate multilateral electricity trade and congestion management. The generators and loads will provide raise and lower bids for congestion relief to their regional transmission operator. The operators will then coordinate their local congestion management decisions, with the help of the decentralized OPF software, in order to maximize their welfares considering risk management.

6. REFERENCES

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