Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 103 (2017) 287 – 294

Procedia Computer Science

XIIth International Symposium «Intelligent Systems», INTELS'16, 5-7 October 2016, Moscow, Russia

Electrical energy supply control support via meters data ellipsoidal approximation in smart grids

G. Chrysostomou[a], V. Shikhin[b]*, A. Shikhina[c]

[a]Frederick University of Technology, Nicosia, Cyprus
[b]Moscow Power Engineering Institute, Moscow, Russia
[c]RT-Soft LLC, Moscow, Russia

Abstract

Paper discusses the approach that supports the decision-making under need to provide total multi-line electrical energy supply under appointed maximum level. The data available from power meters allows to estimate the boarders of acceptable level for the external power supply and to predict its overshoot. It leads to rapid decision-making and allows to avoid the penalties on behalf of the power distribution utilities. Data approximation in the form of ellipsoid gives clear graphics and concise analytical description of the desired boarder. Introduced in the paper algorithm involves logarithmic functional transformation of the target criterion that allows to convert the meter data approximation via maximum volume ellipsoid problem to the convex nonlinear mathematical programming.

Peer-review under responsibility of the scientific committee of the XIIth International Symposium "Intelligent Systems"

Keywords: electrical energy; ellipsoidal approximation; nonlinear programming; power distribution; smart grid

1. Introduction

The need to optimize end-to-end electrical grid efficiency closely related with the mathematical tools applied for measurement data mining, presentation and treatment. The demand from utility dispatchers and operators for clear and ready for direct use forms of measurement data representation is great. Collected data are utilized not only for

* Corresponding author.
E-mail address: ShikhinVA@mpei.ru

Peer-review under responsibility of the scientific committee of the XIIth International Symposium "Intelligent Systems"
doi:10.1016/j.procs.2017.01.109

online power consumption control but also can be used for the working capacity indices estimation and analysis that matches the Smart Grid concept[1,2] and supports the decision-making under need to provide total multi-line electrical energy supply under appointed maximum level[3,4,5]. The method for such data approximation in the form of ellipsoid is represented in this paper and called the Balancing Ellipsoid Method. Method follows the well-known mathematical approaches to approximate the areas via second order geometrical figures[6,7,8,9,10].

2. Formulation

Let the Area of Required Level (ARL) is considered to be the area S in Ω_X, where target criterion $J(X)$ satisfies:

$$S := \{x \in \Omega_x \mid J(X) \le c\}, \tag{1}$$

while outside the area S:

$$J(X) > c, \tag{2}$$

where c is any pre-assigned positive constant; $X=[x_1,x_2,...,x_p]^T$ is the vector of measured variables with components from the space $\Omega_X:=\{x\in R^m\}$ on the variety of real numbers R^m.

Accepted restrictions: a). Criterion $J(X)$ to be numerically valued and continuous, bounded and positively-defined; b). ARL supposed to be convex and constrained; c). Let the absence of sub-regions with non-measurable variables.

Let exists nonempty set S^* which contains elements-points of number $N^*+N^o=N$:

$$S^* = \{\vec{x}_i^* \in R^m \mid J(\vec{x}_i^*) \le c\}, \quad i = \overline{1, N^*} \tag{3}$$

and also exists nonempty set:

$$S^o = \{\vec{x}_i^o \in R^m \mid J(\vec{x}_i^o) > c\}, i = \overline{1, N^o}\ . \tag{4}$$

ARL construction can be formulated as the construction of ellipsoid E^* which includes the most elements from the set S^* and strictly no one from the set S^o. This requirement induces new formulation for ellipsoid search[6].

3. Main result

Suppose ellipsoid with center $\vec{x}_o$ appropriates to the symmetric positively-defined matrix $W,[m\times m]$ with elements $w_{i,j}, \quad i,j=\overline{1,m}$:

$$E = \{\vec{x} : (\vec{x} - \vec{x}_o)^T W (\vec{x} - \vec{x}_o) \le 1\} \tag{5}$$

For clarity put ellipsoid E center into origin $\vec{x}_o = \vec{O}$. Well-known formula for ellipsoid volume:

$$V_E = \frac{V_S}{\sqrt{\det W}} \tag{6}$$

where the volume of m-dimensional hyper-sphere V_S of radius R is calculated through gamma-function $\Gamma(m/2+1)$:

$$V_S = \pi^{m/2}\Gamma^{-1}(\frac{m}{2}+1)R^m \tag{7}$$