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DISTRIBUTED ELECTRICAL ENERGY MANAGEMENT SYSTEM ANALYSIS IN STANDARD GRIDS

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Abstract- Because of the lack of energy sources and various needs of human society to the electrical energy, it is necessary to optimize the use of it that this matter needs an attention to energy management. Basically, traditional EMS designing was centralized, but recent trends in power systems encourage EMS designing to develop towards distributed energy management system. In this paper, energy management and distributed energy management systems in different parts of power system are described. Then, 30 buses and 57 buses standard IEEE grids are clustered and generation and consumption values of active reactive power for these grids are compared. Comparison between these diagrams as well as comparison between standards deviation values related to these grids shows that after energy management implementation, better curves for generation and consumption values of active and reactive power will be achieved.

Keywords: Energy Management System (EMS), Distributed Systems, Standard Grids.

I. INTRODUCTION

According to the parameters such as unmethodical and illogical use of fossil energy (that causes air, soil and water pollution), high rate of population growth and limitation of energy resources in the country, the necessity of optimization of the use of energy is inevitable and a permanent need. So, all of urban systems for survival, growth and development need to regular energy feeding in ideal quality and quantity. Energy is the main base of an urban system.

Scientific definition of energy is capability or capacity of doing work [1] and management is set of skills and knowledge for the optimal use of resources [2]. In the current time, energy is a life quintessence for the human society and electrical energy is one of the most valuable forms of energy.

Because of lack of energy sources and various needs of human society, it is necessary to optimize the use of it that this matter needs to optimize the use of it that this matter needs an attention to energy management [3].

Traditional EMS design is basically centralized, but recent trends in power systems are promoting EMS design to develop towards the form of distributed energy management system (DMS) [4]. Among these trends are [5]:

(a) The proposed extension of computer control to the distribution power system and down to the customer level;

(b) The move to integrate power system operation and control with other corporate functions.

In order to fulfill all these functions, traditional EMS requires a very complex and very expensive communication system with high capacity links, and because there are too much information to be dealt with, traditional centralized algorithms may have difficulties to meet the online requirements of many very important functions. DMS has many advantages over the traditional EMS in many aspects [6]. The present rapid developments of the computer network technology and the communication technology have provided substantial support for the realization of DMS [7].

II. ELECTRICAL ENERGY MANAGEMENT

Energy management causes energy conservation and it is told to the set of actions that is done to the effective use of finite energy sources. These actions contains energy saving, logical energy using and energy sources replacement [3].

Totally, there are five methods for logical use of energy:

1) Abstinence of excessive use
2) Useful energy demand reduction
3) Revenue improvement
4) Energy resumption
5) Use of renewable energy sources [3].

Today, not only management of electrical energy is necessary but also it is an inevitable committal for the supplier of it that is called as the load and consumption management [8]. Load and electricity consumption management means implementation of management ways for consumers to achieve the aims of load factor increase for supplying reliable electricity for subscribers and economical saving that is possible in the two different faces of electrical supply and demand [8].

Load management and energy management are effective on each other and executive techniques that is considered for each of these two topics, has effect on the other. We can study this matter from two points of view: first from consumer's viewpoint and second from planner's viewpoint. Electrical energy management can be done in distribution, transmission and generation parts.

In distribution part, we can reduce energy consumption with methods such as cultural ways of electrical energy consumption, load management, time of use tariff, interval load tariff, distribution system losses reduction (in distribution lines and equipment and consumers equipment), demand management and energy consumption management in lighting systems.

In transmission part, we can reduce losses with transmission losses reduction, crossing power reduction, equipments cyclical inspection and using of suitable equipment with high efficiency.

In generation part, we can implement electrical energy management with optimization of power generation distribution in generation units, consumed fuel cost reduction, environment pollution reduction result in power generation, suitable use of equipment with high efficiency equipment cyclical inspection, and use of renewable energies such as solar energy, hydroelectric, earth heat, wind, biomass, photovoltaic cells and etc.

III. CLUSTERING

Clustering is a division of data into groups of similar objects. Each group, called cluster, consists of objects that are similar between themselves and dissimilar to objects of other groups [9].

K-means clustering is based on input vector classification by distance functions. K-means clustering because of simplicity and ability of large sets of data management is well known. This method is based on sum squares minimization of all points distance to cluster center in a cluster domain [10].

In K-means case a cluster is represented by its centroid, which is a mean (usually weighted average) of points within a cluster. This works conveniently only with numerical attributes and can be negatively affected by a single outlier. On the other hand, centroids have the advantage of clear geometric and statistical meaning [9].

A popular partitioning clustering method is the k-means clustering. This method classifies a given set of elements into a fixed number of mutually exclusive clusters, say k clusters [11]. One of the requirements is that the clusters so formed should have at least one element. To this end, the algorithm proceeds as follows. First, it randomly chooses k centroids, one for each of the k clusters. Then, the remaining data elements are assigned to their nearest centroid [12]. When no element is left over, the initial grouping of elements is completed. Next begins an iterative process where the centroids of the clusters are sequentially recalculated and all the clustering procedure re-executed until the centroid locations do not change anymore [13].

The K-means algorithm [14, 15] is by far the most popular clustering tool used in scientific and industrial applications. The name comes from representing each of K clusters C_j by the mean (or weighed average) c_j of its points, the so-called centroid [16].

Two versions of K-means iterative optimization are known. The first version is similar to EM algorithm and consists of two-step major iterations that (1) reassign all the points to their nearest centroids, and (2) recomputed centroids of newly assembled groups. Iterations continue until a criterion is achieved (for example, no reassignments happen). This version is known as Forgy's [17] algorithm and has many advantages [16].

The second (classic in iterative optimization) version of K-means iterative optimization reassigns points based on more detailed analysis of effects on the objective function caused by moving a point from its current cluster to a potentially new one. If a move has a positive effect, the point is relocated and two centroids are recomputed [16]. There is experimental evidence that compared with Forgy's algorithm; the second (classic) version frequently yields better results [18, 19]. Figure 1 illustrates both implementations.

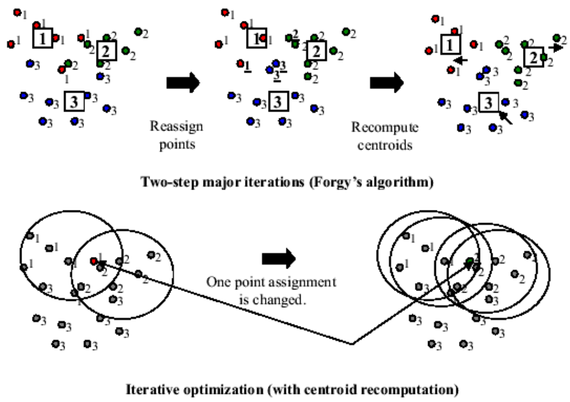

Figure 1. Version of reassign points and recomputed centroids

IV. DISTRIBUTED ENERGY MANAGEMENT SYSTEM

Energy Management Systems (EMSs) are computer-based tools used by power system operators to monitor and control today's increasingly complex power system. The major cost of a DMS is not only the functions themselves, but also the field devices and communications architecture. Thus, it is difficult for most utilities to update their system in only one step [20].

The aim of distributed energy management system is to secure and coordinated operation of high and medium voltage transmission grids throughout the system. Equipment control in all voltage levels with a system and in a similar matter does by DMS specifications in comparison with common SCADA systems. Implementation and operation of the decentralized energy management system DMS for

- Minimizing energy costs
- Maximizing the use of renewable energy
- Maximizing the network utilization and prevention of local network overloads.

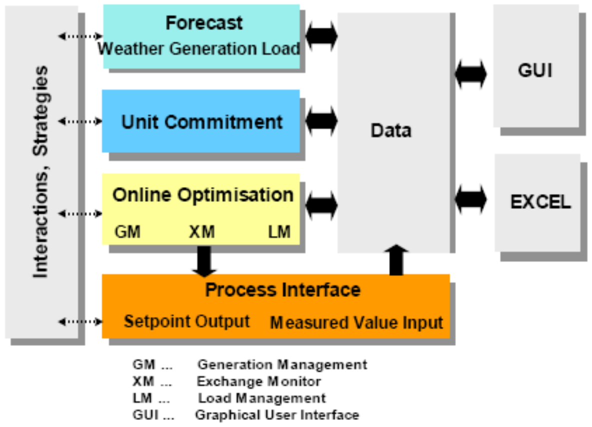

Figure 2. Structure and functionality of the decentralized energy management system 'DMS'

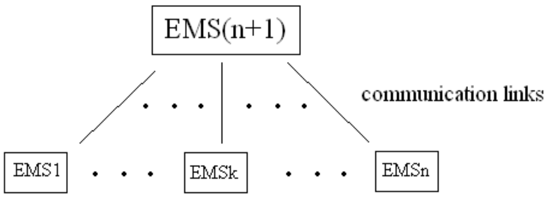

Figure 3. The Two-level hierarchically coordinating mechanism of a DMS

The principle of DMS is presented in Figure 2 [21] and the mathematical model is shown in Figure 3. Suppose that a large-scale power system is divided into n subsystems which may not have the same size and a boundary subsystem which is only composed of all boundary nodes and lines, e. g. let S_i be the node set of some subsystem, then we have

$$S_p \cap S_q = \varphi \qquad p,q = 1,...,n$$

$$S_k \cap S_{n+1} = S_{bk} \qquad k = 1,...,n \qquad (1)$$

$$\bigcup_{k=1}^{n} S_{bk} = S_{n+1}$$

where φ is an empty set, S_{bk} is the set of the boundary nodes of the kth subsystem and S_{n+1}, is the node set of the boundary subsystem [14].

Suppose also that in each subsystem there is a control centre (EMS) which only monitor and control its own subsystem while it communicate with EMSs of other subsystems to get necessary information through the EMS in the boundary subsystem, we have presented a two-level hierarchally Coordinating mechanism model for a DMS (Figure 3) [7].

This coordinating mechanism model has great flexibility and can be easily applied to multi-level hierarchically controlled power systems. In a multi-level coordinating mechanism model, the up-per level coordinator gets information just from its lower level EMSs which may be the coordinators of their own lower level EMSs [7].

After clustering and simplification of huge power system to the smaller power systems, electrical energy management in all power system parts, e.g. generation, transmission and distribution, is simplified and it will be needed to more simple and smaller control and management equipment. Also, with development and enlargement of power system, it is not needed to development and promotes all of the management equipment, because system clustering can help to consider the future development of power system as a new cluster and to prepare management and control equipment as much as those cluster.

V. SIMULATION

In this paper, distributed energy management system is studied on two IEEE standard power systems, e.g. 30 buses and 57 buses systems. Due to simulation on these systems, first, discussed system is clustered by MATLAB7.4 software and with K-means method clustered power system that achieved, is managed in generation, transmission and distribution parts with management methods. Then, by PSAT toolbox and in MATLAB7.4 software environment, load dispatching is done for studied systems. At last, achieved results by EXCEL2003 software are classified, drown and presented and are compared for before and after management states.

Due to power system lines and buses clustering and separating, we can separate lined which have less flow and exchange with each other, and consider them as separate clusters. The lines that have more exchange with each other can be in a cluster, as well.

Whereas Jacobian matrix can be a suitable criterion for determine the value of active and reactive power flow in buses and power system, for studied power system clustering is a suitable criterion too, and whereas in this case, active power flow value is more important rather than reactive power flow value, just first n array in Jacobian matrix (n: system buses number) is used for clustering that show active power flow value.

For clustering of under study power system, we use MATLAB7.4 software and Wavelet toolbar in this software. Power consumption process during 24 hours in one day, is borrowed from IEEE standards suggested values in one of the non-holiday days of week in winter.

Table 1. Clustering results for 30 buses IEEE standard grid

Buses number	Cluster number
9, 10, 11, 17, 21, 22	1
1, 2, 3, 4, 5, 6, 7, 8, 28	2
24, 25, 26, 27, 29, 30	3
12, 13, 14, 15, 16, 23	4
18, 19, 20	5

Clustering results for 30 buses IEEE standard power system is presented in table 1. For this power system cluster numbers is considered equal to 5 arbitrarily. Table 2 presents standard deviation for 30 buses IEEE standard grid. The values show that after energy management implementation, better diagram will be achieved for consumption and generation. Figures 4 and 5 show a comparison between generated active and reactive power for 30 buses IEEE standard grid, for both before and after implementation of electrical energy management.

Table 2. Standard deviation for 30 buses IEEE standard grid

	Generated reactive power	Generated reactive power	Consumed active power	Consumed reactive power	loosed active power	loosed reactive power
before	12.212	3.183	16.701	27.906	29.224	31.086
after	10.889	2.806	14.246	24.839	25.400	26.687

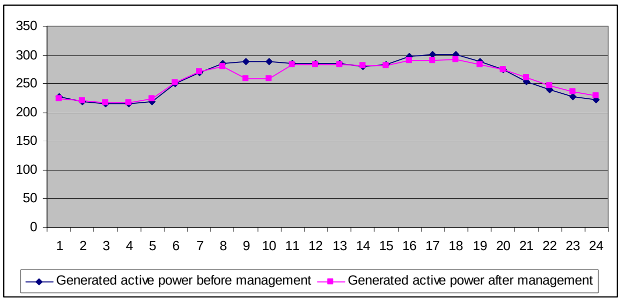

Figure 4. Comparison between before and after implementation of electrical energy management for active power generation for 30 buses IEEE standard grid

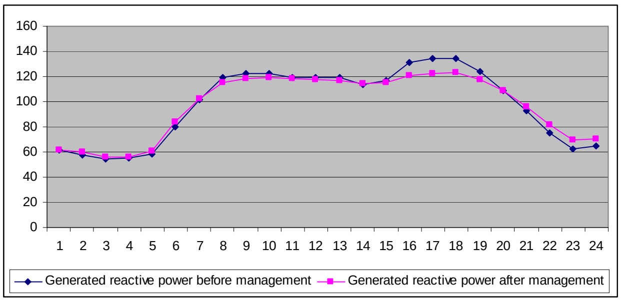

Figure 5. Comparison between before and after implementation of electrical energy management for reactive power generation for 30 buses IEEE standard grid

Table 3. Clustering results for 57 buses IEEE standard grid

Buses number	Cluster number
24, 25, 26, 30, 31, 32, 33	1
10, 12, 16, 17, 51	2
8, 9, 11, 41, 42, 43, 55, 56, 57	3
34, 35, 36, 37, 39, 40	4
13, 14, 46, 47, 48, 49, 50	5
7, 27, 28, 29, 52, 53, 54	6
19, 20, 21, 22, 23, 38, 44	7
1, 2, 3, 4, 5, 6, 15, 18, 45	8

Table 4. Standard deviation for 57 buses IEEE standard grid

	Generated reactive power	Generated reactive power	Consumed active power	Consumed reactive power	loosed active power	loosed reactive power
before	23.323	5.443	42.129	136.014	65.509	140.331
after	18.797	4.364	37.159	113.669	56.158	117.919

Table 4 presents standard deviation for 57 buses IEEE standard grid. The values show that after energy management implementation, better diagram will be achieved for consumption and generation.

Figures 6 and 7 show a comparison between consumed active and reactive power for 57 buses IEEE standard grid, for both before and after implementation of electrical energy management.

Table 5. Power factor values after implementation of energy management for 14 buses and 30 buses IEEE standard grids

hour	Power factor	
	30 buses	57 buses
1	0.9312	0.9669
2	0.9296	0.9688
3	0.9298	0.9687
4	0.9296	0.9685
5	0.9288	0.9886
6	0.9312	0.9670
7	0.9219	0.9649
8	0.9149	0.9647
9	0.9147	0.9646
10	0.9147	0.9644
11	0.9153	0.9652
12	0.9154	0.9651
13	0.9153	0.9652
14	0.9170	0.9654
15	0.9160	0.9648
16	0.9140	0.9641
17	0.9135	0.9657
18	0.9135	0.9657
19	0.9133	0.9650
20	0.9170	0.9644
21	0.9184	0.9655
22	0.9263	0.9661
23	0.9315	0.9678
24	0.9239	0.9665
Total	0.9201	0.9658

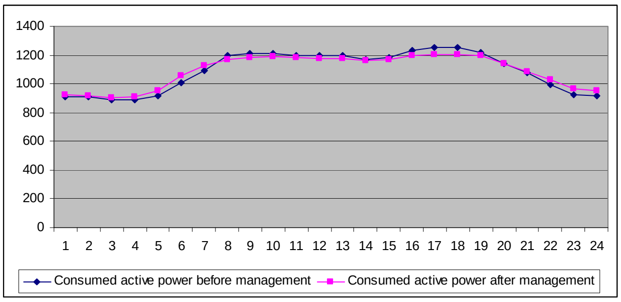

Figure 6. Comparison between before and after implementation of electrical energy management for active power consumption for 57 buses IEEE standard grid

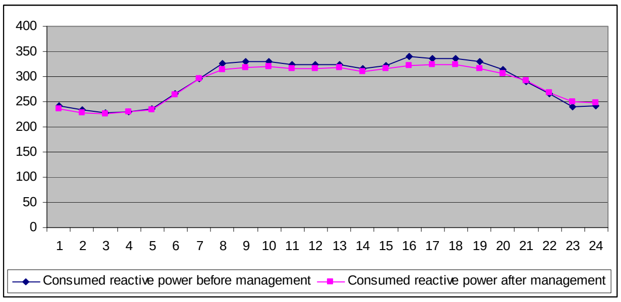

Figure 7. Comparison between before and after implementation of electrical energy management for reactive power consumption for 57 buses IEEE standard grid

VI. CONCLUSIONS

It is some decades that power system observation and controlling is done in a central structure, with an SCADA and energy management system placed in a control center. In recently established markets, traditional management systems were not sufficient, and there is a need to distributed management infrastructures to ease interactions between market participants.

For clustering and separating lines and buses of power system, separate lines that have less power exchange and flow with each other, and consider them as the separated clusters, also lines that have more power exchange with each other can totally place in one cluster.

Clustering helps to power system engineer does management in smaller regions than total of the system. Also, after clustering and simplification of power system to smaller systems, electrical energy management has eased in all parts and there is the need to easier management and control equipment. And with development and enlarging of power system, there is no need to develop and promote all of the management equipment, because system clustering can help future power system developments to be considered as a new cluster and, management and control equipment prepare as much as that cluster.

This matter will lead to lower investments and management equipment expenses. Distributed electrical energy management helps to reduce generating power expenses and pollution of generation. Primary investments and equipment management expenses will reduce as well.

Comparison between simulation results after electrical energy management implementation shows that:

1) Generated active and reactive power values that is demanded, is reduced, and the power curves are become smoother.
2) Consumption reactive power values are decreased.
3) Consumption active power value is decreased and consumption curves value is smoother too, and load factor is become closer to 1.
4) Due to decrease of consumption generation power, power losses are also decrease.
5) Power factor after management implementation is modified too, and is become closer to 1.
6) Clustering helps to simplify electrical energy management.

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BIOGRAPHIES

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