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Evaluation Algorithms for Multiple Function of Dispersed Electrical Energy Storage Systems

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Abstract – With the increase of electrical consumption and the unbalance of power demand and supply, power reserve rate is getting smaller and also the reliability of the power supply is getting deteriorated. Under this circumstance, the electrical energy storage (EES) System is considered as one of essential countermeasure for demand side management. This paper proposes efficient evaluation algorithms of multiple functions for EES systems, especially the secondary battery energy storage systems, in the case where they are interconnected with the power distribution systems. It is important to perform the economic evaluation for the new energy storage systems in a quantitative manner, because they are very costly right now. In this paper, the multiple functions of EES systems such as load levelling, effective utilization of power distribution systems and uninterruptible power supply are classified, and then the quantitative evaluation methods for their functions are proposed. From the case studies, it is verified that EES systems installed at distribution systems in a dispersed manner have multiple functions involved with direct and indirect benefits and also they can be expected to introduce to distribution systems with respects to economical point of view.

Keywords: Electrical energy storage systems, Distribution systems, Successive approximation method, Present worth method, Uninterruptible power supply.

1. Introduction

Recently, the operation of electric power systems has become more difficult because the peak load demand is increasing continuously and also the daily and annual load factors are worsening. Furthermore, the global environmental issues are required in the electric power systems. One countermeasure to overcome these problems is a study on the operation method of the electric power systems including new energy storage systems such as superconducting magnets(SMES), secondary batteries and flywheels. They have made remarkable advances lately and will be applied practically to a great advantage in the near future. It is thus necessary to establish a mathematical method on the multiple functions of EES systems. However, most of previous approaches are based on the load levelling of total power system and annual load duration curve [1-3]. This paper concentrates on the multiple functions such as load levelling in both power systems and distribution systems, effective utilization of power distribution systems and uninterruptible power supply. They are evaluated by the quantitative methods, which are the successive approximation solution, the analysis of present worth and the concept for interruption cost.

The proposed evaluation algorithms are mainly composed of three parts according to the multiple functions of EES systems. At the first part, the successive approximation solution considering both the optimal generation mix and optimal operation of EES systems is developed to evaluate the benefits of the load levelling for EES systems. Since the operating mode of EES systems is dependent to the storage capacity(kWh) unlike conventional generators, they cannot operate the desired power continuously. Therefore, the appropriate load model which reflects the operating strategies of EES systems should be used to determine the optimal generation mix. The second part presents the evaluation method using the present worth analysis to model the benefits of effective utilization of distribution facilities in the case where EES systems are operated at the distribution substation during the peak hours. And the last part proposes the concepts of expected interruption cost to evaluate the uninterruptible power supply of EES systems. Numerical examples are shown in order to indicate the efficiency of the proposed algorithms. From the simulation results, it is verified that EES systems can be commercialized and introduced to power distribution systems in the near future.

2. Categorization of Applications in ESS Systems

Recently several types of storage technologies are widely used in small and large size for usecase such as

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residential, industrial, utility and renewable stabilization applications. The high energy and power density of these technologies are very attractive for stationary applications such as peak shaving and load levelling for demand side management and power smoothing for renewable energy systems and so on. At first, Utilities constantly need to prepare supply capacity and transmission/distribution lines to cope with annually increasing peak demand, and consequently develop generation stations that produce electricity from primary energy. If EES systems suppress peak demand, it can reduce investment in power system infrastructure such as transformers, transmission lines and distribution lines through peak shaving in certain areas at times of peak demand. It can postpone investment needed by mitigating network congestion through peak shift [4, 5].

And also, generally generation cost can be reduced by storing electricity at off-peak times, for example at night, and discharging it at peak times. If the gap in demand between peak and off-peak is large, the benefit of storing electricity becomes even larger. The result is load levelling by time shifting. Using EES systems to decrease the gap between daytime and night-time may allow generation output to become flatter, which leads to an improvement in operating efficiency and cost reduction in fuel. For these reasons many utilities have constructed pumped hydro, and have recently begun installing large-scale batteries at substations. Furthermore, in order to solve global environmental problems, renewable energies such as PV system and wind power system will be widely used. The integration of renewable energies into the electric power grid can cause problems of output fluctuation and unpredictability. When the total volume of renewable energies connected to the grid exceeds a certain level such problems will appear and countermeasures will be needed. In order to stabilize the fluctuation and to match the supply and demand of energy, EES system is essential for the introduction of large amounts of renewable energy [6].

And also, EES system can maintain power quality such as voltage and frequency, by supplying/absorbing power from/into EES system when necessary. And the penetration of renewable energy requires more frequency control capability in the power system. EES system can be used to enhance the capability through the control of charging and discharging from network operators, so that the imbalance between power consumption and generation is lessened.

3. Evaluation Algorithm for Multiple Functions of EES Systems

3.1 Multiple Functions of EES Systems

Two major cases of the allocation sites for EES systems can be generally considered. One is transmission substation bus consisting of generator units and power transmission systems and the other is a distribution substation bus including the customers. However, the latter is considered more effective as the allocation sites of EES systems, because the multiple functions of EES systems can be demonstrated effectively even if EES systems have a small capacity. By allocating the EES systems to the distribution system bus(distribution substation) as shown in Fig. 1, the direct benefit of the load levelling for both the total power system and distribution system can be expected, and indirect benefit appendant to the direct benefit can also be expected, such as reduction of the investment cost by the effective utilization of distribution system facilities and reliability improvement by the uninterruptible power supply.

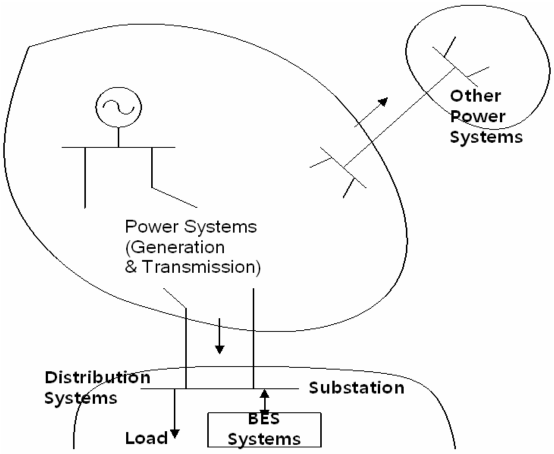

Fig. 1. Model power system with EES systems

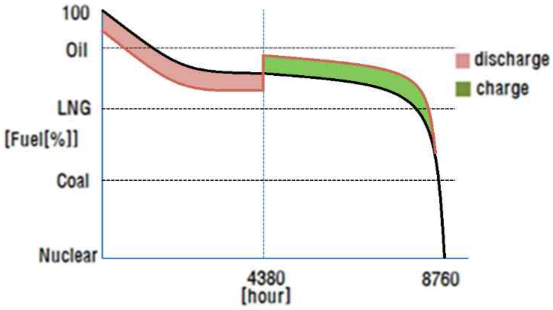

Fig. 2. Concept of load duration curve with EES systems

3.2 Load levelling of EES systems

3.2.1 Concepts of Load Levelling

With the allocation of EES systems to distribution systems, the simultaneous load levelling of both the total power system and distribution systems increases the utilization rates of less expensive generator units, and the benefit for the reduction of the total power operation cost is expected as shown in Fig. 2. In other words, the operation problem of the load levelling is to decide the most appropriate type and number of generators, called an optimal generation mix, in case where EES systems are introduced and operated to distribution systems [2, 3].

The optimal generation mix with EES systems is a static problem against the time period and in which the objective is to determine the process in such a manner as to minimize the total cost for load demands provided for a target year. It must be optimized for both the generation mix (nonlinear integer programming problem) and the operating mode of EES systems (nonlinear programming problem). The problem can be thus formulated and solved as a nonlinear mixed integer programming problem. However, the nonlinear mixed integer programming problem will become rapidly impracticable when the size of the problem increases. In this paper, the successive approximation solution, in which the screening method and the gradient method are combined, is developed to overcome this difficulty [7-10]. The optimization problem stated above is divided into two sub-problems which must be optimized successively as the following section.

3.2.2 Problem Formulation

The optimal generation mix problem with EES systems, whose objective is to determine the generation mix that minimizes the total cost at the target yea, is formulated as a nonlinear mixed integer programming problem as follows :

$$\mathrm{Min} F_n(x,v) = \sum_{i=1}^{n} [\{a_i x_i + b_i Q_i(X_{i-1}, X_{i-1}+x_i, v)] + a_s x_s \quad (1)$$

$$\text{Subj. to } \sum_{i=1}^{n} x_i + x_s \geq P_D + P_R \quad (2)$$

$$x_{i\min} \leq x_i \leq x_{i\max,} i = 1,\ldots,n \quad (3)$$

$$v_{i\min} \leq v_{ik} \leq v_{i\max,} i = 1,\ldots,n, k = 1,\ldots,T \quad (4)$$

where,

$$Q_i(X_{i-1}, X_{i-1}+x_i, v) = \sum_{k=1}^{K}\left[z_k \int_{X_{i-1}}^{X_{i-1}+x_i} L_k(u,v)\,du\right], i = 1,\ldots,n \quad (5)$$

$$X_i = \sum_{k=1}^{i} x_k, i = 1,\ldots,n, X_0 = 0 \quad (6)$$

The symbols used in the above equations are shown in Table 1 and index s denotes the EES systems.

The problem formulated as indicated above, which is composed of two kinds of variables such as generation mix (x) and operating mode of EES systems (v), is a nonlinear mixed integer programming problem. From a theoretical viewpoint, the problem can be solved by evaluating the objective function for all combinations of generation mix (x) which satisfy Eqs. (2)~(4). However, this method will become rapidly complicated with the increase of system size. In this paper, the optimal generation mix with EES systems are decided under the following assumptions [11, 12] :

Table 1. List of symbols

F_n	: total cost at target year
n	: the number of generation types
a_i , b_i	: fixed and variable cost of generation type i
x_i , x_s	: capacity of generation type i and EES systems
a_s	: fixed cost of EES systems
v_{ik}	: output power of EES systems at daily load curve i and time period k
Q_i	: annual energy production for generation type i
X_i	: cumulative capacity up to generation type i
$L_k(u)$	: fraction of time that demand equals or exceeds load level u at duration curve k
z_k	: the number of days that provides L_k (u)
P_D, P_R	: peak demand and spinning reserve
K	: the number of patterns of daily load duration curve
T	: the number of time periods for daily load duration curve

ⓐ Total cost of generators is composed of the sum of the variable cost and fixed cost and total cost of EES systems is composed of the fixed cost only.

ⓑ Generator maintenance is ignored.

ⓒ Unit sizes for the existing generators are previously provided and unit sizes for new generators are not fixed.

3.2.3 Algorithm for load levelling application

In this paper, an efficient method based on the successive approximation technique is developed to overcome the above difficulty. The optimal generation mix problem with EES systems is divided into following two sub-problems :

(1) Optimal generation mix problem for generators only, where the operating mode of EES systems is fixed (nonlinear integer programming problem).

(2) Optimal operation problem of EES systems, where the generation mix is fixed(nonlinear programming problem).

These are optimized successively fixing the amount of added EES systems. As the optimization technique for solving above sub-problem (1), this paper adopts the extended screening method, which can handle the existing generators in approximate manner. And the optimization technique for solving above sub-problem (2) is described in the next section. The optimization procedure is summarized as follows :

<step 1> Assume system parameters. Put K_0=0 (fixed cost of EES systems) and X_0=0 (initial capacity of EES systems).

<step 2> Decide the optimal generation mix for generators only (**x**) fixing the output power of EES systems to zero (**v** = 0). Use F_0 for the total cost of this solution.

<step 3> Decide the optimal operating mode of EES systems (**v**) fixing the generation mix (**x**). And calculate the optimal generation mix with EES systems Fs.

<step 4> If $F_s \leq F_0$, add the unit size of EES systems ΔX and go to <step3>. Otherwise, go to next step.

<step 5> If the introduction capacity of EES systems is zero (X = 0), the algorithm terminates. the generation mix (**x**) and the capacity and fixed cost of EES systems are the optimal solution. Otherwise, increase the unit fixed cost of EES systems ΔK and go to <step3>.

The detailed flowchart of the above algorithm is shown in Fig. 3. In this figure, ESS systems represents EES systems and Δ denotes a small unit size for the capacity and fixed cost of EES systems.

3.2.4 Optimal Operation of BES Systems

In this section, the algorithm, which decides the optimal operation of EES systems fixing the generation mix, is described. The gradient method is used for determining the optimal operation mode of EES systems. The economic operating condition for the energy storage system is provided as follows :

$$\eta > \frac{\lambda_{charge}}{\lambda_{discharge}} \tag{7}$$

where, η : round trip efficiency of EES systems, $\lambda_{\mathrm{charge}}$: incremental cost in charging period, $\lambda_{\mathrm{discharge}}$: incremental cost in discharging period.

The minimization for the objective function F_n, where the generation mix is fixed, is obtained by the load levelling so as to satisfy the economic operating condition. In this procedure, the output power(kW) and storage capacity(kWh) constraints for EES systems must be also satisfied. The optimal operation mode of EES systems over the target year is decided when the following algorithm is applied to all daily duration curves. The procedure is as follows :

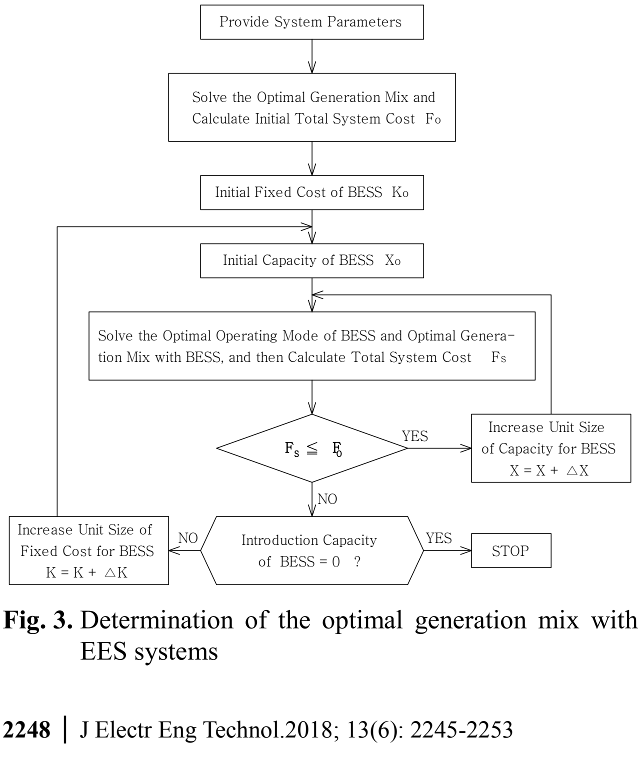

Fig. 3. Determination of the optimal generation mix with EES systems

<step 1> Select the lowest and highest demand periods out of the daily load duration curve. And calculate the incremental costs $\lambda_{\mathrm{charge}}$ and $\lambda_{discharge}$.

<step 2> If $\eta < \lambda_{\mathrm{charge}} / \lambda_{discharge}$, the algorithm terminates. Otherwise, let charge a small amount of power ΔP_s in the lowest period, and discharge the power $\eta \Delta P_s$ in the highest period.

<step 3> If the maximum storage capacity(kWh) constraint is reached, the algorithm terminates.

<step 4> If the maximum output(kW) constraint for EES systems is reached, eliminate the period from the consideration. Go to <step1>.

In additions, the allocation site of each small amount for EES systems is decided by selecting the lowest F_n (x) for the cases where the above algorithm is applied at all allocation sites which are the distribution substations.

3.3 Effective utilization of distribution facilities

3.3.1 Concepts of effective utilization

The expansion planning of the electric facilities in distribution systems is usually performed considering the utilization rate related to the increase of peak demand in distribution systems. If EES systems allocated to distribution systems are used as power source during the peak hours, the economic benefit can be expected. In other words, the investment cost of the facilities is reduced because the starting year of the expansion construction for the distribution facilities can be delayed during some years. In order to evaluate the benefit quantitatively, this paper adopts the present worth analysis [13, 14].

3.3.2 Present worth analysis

The present worth analysis is one of the simple method for the economical assessment. It deals with the comparison process of the investment costs for some alternative plans. It is evaluated by converging the investment costs occurring at different years to present values of basis year. It can be expressed by the present worth factor for a single payment.

$$V^n = \frac{1}{(1+i)^n} \tag{8}$$

where, V^n : present worth factor, i : interest rate, n : target year.

The relationship between the present worth factor and the cumulative present worth factor A_n can be denoted by :

$$A_n = V^1 + V^2 + V^3 + \ldots + V^n$$
$$= \frac{(1-V^n)}{i} = \frac{\left(1 - \frac{1}{(1+i)^n}\right)}{i} \tag{9}$$

Thus, the cumulative present worth (B_n) of investment cost corresponding to the expansion construction beginning at the year 'n' during the total target year, can be obtained as follows :

$$B_n = A_n - A_{n-1} \tag{10}$$

3.3.3 Evaluation algorithm for EES systems

For the cases where EES systems are operated in distribution systems, the economic operating condition can be expressed by Eq. (11). The most economical point is where the expansion investment cost without EES system is equal to the sum of expansion investment cost with EES systems and the investment(capital) cost of EES systems.

$$C_{without} \le C_{with} - C_{ess} \tag{11}$$

where, $C_{without}$: investment cost without EES systems, C_{with} : investment cost with EES systems, C_{ess} : capital cost of EES systems.

Each alternative plan may have several investment costs of expansion construction during the total target year. Therefore, the present worth of each alternative plan can be expressed by Eq. (12), considering the carrying charge rate which includes the return, depreciation and taxes.

$$C_{alter} = \sum_{m} \sum_{n=1}^{N} K_m \alpha_m B_n \tag{12}$$

where, C_{alter} : cumulative present worth, K_m: construction cost, α_m : carrying charge rate, n: target year starting expansion construction, N: total target year, m : the number of facility related to expansion construction, alter: the number of alternative plan.

By substituting Eq. (12) into Eq. (11), the total present worth cost, called the capital (investment) cost of EES systems, can be obtained. This is the economical benefit caused by the effective utilization of the distribution facilities according to the operation of EES systems in distribution substations. It may be called the credit of distribution system.

3.4 Uninterruptible power supply

3.4.1 Concepts of uninterruptible power supply

If EES systems are operated as the load levelling in distribution systems at the normal conditions and as the uninterruptible power supply in fault areas at the emergency conditions, the reliability improvement of power supply in fault areas can be expected. In other words, the benefits represents the cost avoiding interruption by the operation of EES systems when the fault is occurred. In order to evaluate the benefits of the uninterruptible power supply quantitatively, this paper adopts the concepts of expected interruption cost [15, 16].

3.4.2 Expected interruption cost

An interruption cost can be expressed by several factors such as duration time of interruption, occurring time of fault and load characteristics of fault areas. It can be usually formulated by a quadratic equation of the duration time of interruption as follows :

$$F_{iju}(t) = \left(at^2_{ij} + bt_{ij} + c\right) L_{iju} \tag{13}$$

where, $F_{iju}(t)$: interruption cost(Won per kW), t_{ij} : duration time of interruption, L_{iju} : load amount of interruption, a, b, c : the coefficients of load characteristics (interruption cost), i, j: the number of substation and primary feeder, u : the number of time interval.

According to the allocation of EES systems to distribution systems and the operation of uninterruptible power supply at fault, the interruption cost of Eq. (13) can be reformed as follows :

$$F_{iju}(t, x_i, y_i) = \sum_{j \in L_0} F_{iju}\left[t_{ij}, L_{iju}(x_i, y_i)\right] +$$
$$\sum F_{iju}\left[t'_{ij}, L_{iju}(x_i, y_i)\right] \tag{14}$$

where, x_i , y_i : kW and kWh introduction capacity of EES systems, L_0 : [j || primary feeder unsupplied by EES systems at t = 0], t'_{ij} : $t_{ij} - t_{sij}$, t_{sij} : duration time supplied by EES systems after fault.

By considering a restoration probability for the duration time interval of interruption, an expected interruption cost for the entire time interval can be expressed as follows :

$$F_{tot} = \sum_i \sum_j \int_{U_s}^{U_e} A_{iju} \int_0^{\infty} p_{ij}(t) F_{iju}(t, x_i, y_i)\, dtdu \tag{15}$$

where, F_{tot} : total expected interruption cost, $U_s \sim U_e$: total time interval, A_{iju} : interruption probability at time interval U, p_{ij} (t) : restoration probability.

4. Case Studies

4.1 Load levelling applications

To test validity of the proposed method, we carried out simulations using the model systems and parameters as shown in Fig. 4 and Table 2. The table is the data of the statistical materials of Korea Electric Power Cooperation in the fiscal year of 2014. The four load patterns for distribution substations (A, B, C, D) and the peak demand of 10 million kW in Fig. 5 are considered. This figure is the typical load pattern in summer and the load patterns of other seasons are assumed by the same pattern and the size of 70%, 80% and 90% based on the typical load pattern. Furthermore, the round trip efficiencies for EES systems of 70% and 80% are also assumed.

By comparing the total operation cost $F_n(x)$ and $F_0(x)$ for the two cases where EES systems are introduced and not introduced, with the increase of a small unit of the capacity and fixed cost of EES systems, the optimal capacity and fixed cost of EES systems are obtained as shown in Fig. 6. Because of the computation time for the parameter analysis, a small unit of the capacity of EES systems are considered as 20MW(160MWh, 8Hr) and the fixed cost of EES systems is considered as 1000 Won, respectively. Fig. 6 shows that the benefits of the load levelling of EES systems in the distribution substations, which is the fixed cost (C_a), becomes 75~94 thousand Won per kW.

As we can see the figure, the marginal and saturated fixed costs are also obtained. The marginal cost, in which the composition ratio of EES systems is zero, represents the economical point for EES systems. And the saturated fixed cost keeps a constant value although the fixed cost changes, because the complete load levelling is accomplished at each fixed cost. In additions, Table 3 is the comparison results for the composition ratios of generation units and total cost at fixed cost of 75 thousand Won for the two cases where EES systems are introduced and not introduced.

Table 2. Parameters of generation units

Type	Variable Cost (Won/kWh)	Fixed Cost (Thousand Won/kW)	Rating (MW)	Failure Rate(%)
Nuclear	39.7	2,385	-	6.5
Coal	60.9	1,399	1,000	7.0
LNG	147.2	576	1,000	6.0
Oil	184.7	576	-	6.0
ESS	-	Ca	20(8Hr)	-

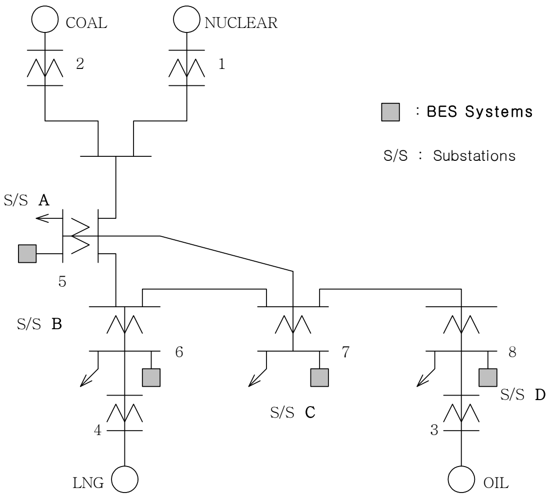

Fig. 4. Model power systems

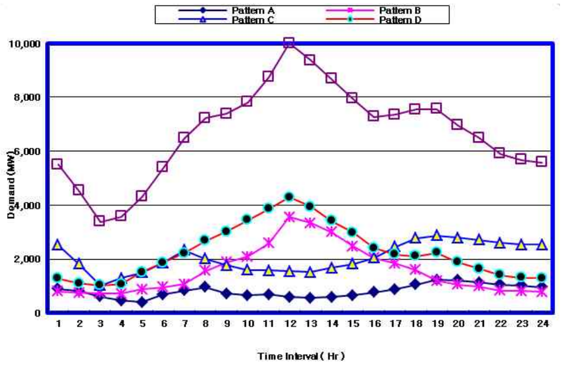

Fig. 5. Yearly load patterns of distribution substations

4.2 Effective utilization of distribution facilities

This paper carries out the simulation using the system

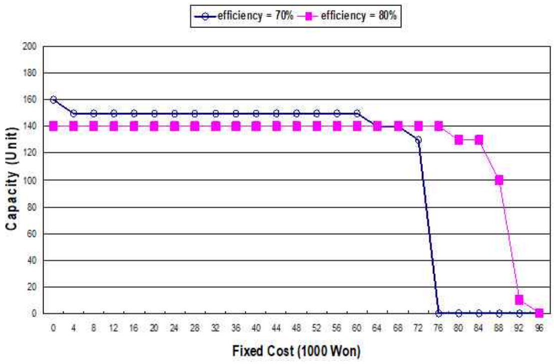

Fig. 6. Optimal capacity and fixed cost of EES systems (1Unit : 20MW, 180MWh)

Table 3. Composition ratio of generation units and total cost (at fixed cost of 75,000Won)

Type	Output Power without EES Systems (MW)	Output Power with EES Systems (MW)
Nuclear	2,899.3	3,766.3
Coal	1,000.0	1,000.0
LNG	1,000.0	1,000.0
Oil	5,100.0	2,399.1
EESS	0.0	2,600.0
Total Cost	1,920.1 Million Won	1,914.1 Million Won

Table 4. System parameters

	Unit Size	Cost (Thousand Won)	Carrying Charge Rate (%)
Distribution Substation(S/S)	45/60MVA x 2	5,911,800	9.2
Bank (M.Tr)	45/60MVA	773,540	9.2
EESS	7MW	Cb	12.0

(*) The cost of bank is 30% of S/S and M.Tr is Main Transformer

Table 5. Expansion planning of distribution systems (annual load increase : 5%)

Year	Total Load (MW)	Without EES Systems				With EES Systems				
		S/S (MW)	Bank (MW)	Total Bank (MW)	Utilization Rate (%)	EES (MW)	S/S (MW)	Bank (MW)	Total Bank (MW)	Utilization Rate (%)
1	255	54×2		54×8	59.0	7×2			54×6	74.4
2	268			〃	62.0	〃			〃	74.1
3	281			〃	65.5	〃			〃	73.8
4	295			〃	68.3	〃			〃	73.8
5	310			〃	71.8	〃			〃	74.1
6	326		54×1	54×9	67.1	〃			〃	74.7
7	342			〃	70.4		54×2		54×8	59.7
8	359			〃	73.9				〃	63.7
9	377	54×2		54×11	63.5				〃	67.8
10	396			〃	66.7				〃	72.2
Total Cost (Million Won)		4522.5	459.3	4981.8	66.8	42Cb	1163.6	-	1163.6	70.8

(*) S/S denotes distribution substations and the total cost is the sum of the present worth in each facility

parameters of Table 4 and some following assumptions. The total number of distribution substation of 6 units (60MVA×6) and the peak demand in basis year of 270MVA (243MW) are assumed, respectively. The peak demand is 75% of the capacity of total substations and the power factor is 90%. The annual load increase of 5% and interest rate (i) of 10% are also assumed.

The expansion schedule for the two cases where EES systems are introduced and not introduced in distribution substations is obtained as shown in Table 5. The table indicates that the total utilization rates of the case where EES systems is introduced is improved by 4% compared to the case where EES systems are not. And the table also shows that the starting year of the expansion construction of distribution facilities for the case where EES systems are introduced is delayed for 6 years.

From the last row of the table, the benefit of effective utilization of distribution facilities, C_b, becomes about 90 thousand Won per kW for the 10 years expansion planning. In addition, this value may be added and increased by the expansion construction cost of the underground cable (or overhead transmission line, 154kV), by which distribution substations are connected to the transmission network.

4.3 Uninterruptible power supplies

By using the model systems of Fig. 7 and Table 6, the benefits for the avoided cost of the interruption by the uninterruptible power supply is obtained by the comparision of the total expected interruption costs for two cases where EES systems are introduced and not introduced. Fig. 8 shows that the benefits of EES systems becomes about 13 thousand Won per kW for one year in case of the industrial area. The figure also shows the benefits according to the three load types such as residential area, commercial area and industrial area. It is clear that the EES allocation site of EES systems is the industrial area because it has the largest coefficient of interruption cost.

Table 6. Coefficient values of interruption cost

	a1 (Peak Hours)	a2 (Middle Hours)	a3 (Off-peak Hours)
Residential Area	0.002	0.007	0.002
Commercial Area	0.002	0.025	0.01
Industrial Area	0.01	0.03	0.02

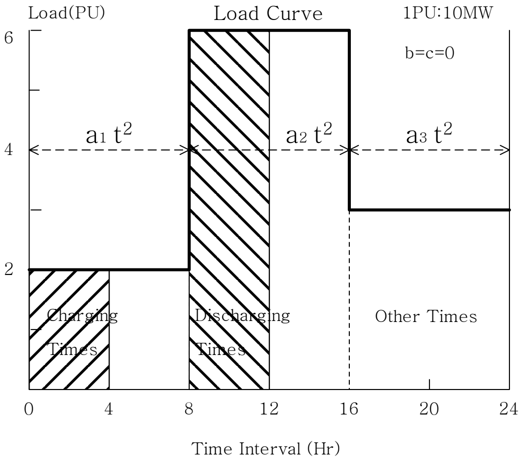

Fig. 7. Daily load curve and operation mode of EES systems

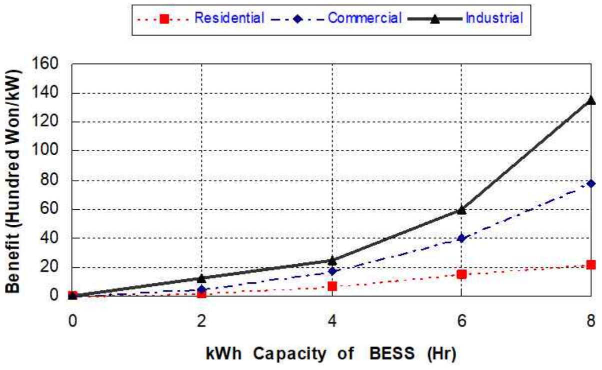

Fig. 8. Benefits of uninterruptible power supply

5. Conclusions

This paper presents the efficient algorithms of the multifunction for EES systems interconnected with distribution systems. The economical benefits of EES systems are evaluated by the quantitative methods such as successive approximation solution, present worth analysis and interruption cost conception. The simulation results by using the model system and parameters, are summarized as follows :

(1) The benefits of the load levelling by the operation of EES systems in the distribution substations, which is the fixed cost (C_a), is 75~94 thousand Won per kW for one year. By considering the carrying charge rate of 12%, this value becomes 625~783 thousand Won per kW. And the marginal and saturated fixed costs is also obtained. The marginal cost is the economical point for the introduction of EES systems.

(2) The total utilization rates with EES systems is improved by 4% compared to without EES systems and the starting year of the expansion construction is delayed for 6 years. Therefore, the benefit of effective utilization of distribution facilities (C_b) becomes about 90 thousand Won per kW for the 10 years expansion planning.

(3) The benefits for the avoided cost of the interruption by the uninterruptible power supply of EES systems is about 13 thousand Won per kW for one year and the optimal allocation site of EES systems is selected as the industrial area with the important load characteristics.

From the simulation results, it is verified that EES systems can be economically introduced and operated to distribution system in the near future.

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