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Power Supply & Storage Capability Index of Smart Grid and its Application

Abstract. *In distribution network, the interconnection of distributed energy storage system (DESS) provides network with supply & storage capability which is conducive to regulate peak load and solve intermittency of intermittent energy source. DESS power supply & storage capability index is proposed to quantitatively describe the time-varied maximum power supply and storage capability of DESS, considering the effect caused by interconnection of DESS and the constraint of electrical network and DESS. The supply & storage capability index's effectiveness is verified under the context of DESS optimal economic scheduling.*

Streszczenie. *W artykule przedstawiono zagadnienie oceny zdolności wytwarzania i gromadzenia energii elektrycznej w systemach typu DES (ang. Distributed Energy Storage). W tym celu zaproponowano indeks, określający wielkości maksymalne wymienionych czynników, uwzględniający możliwość łączenia DES między sobą i z siecią. Opisano sposób weryfikacji otrzymanego parametru. (**Współczynnik zdolności wytwarzania i magazynowania energii elektrycznej w sieci inteligentnej oraz zastosowanie).***

Keywords: smart grid; distributed energy storage; supply & storage capability; optimal scheduling.
Słowa kluczowe: sieć inteligentna, rozproszone magazyny energii, zdolności produkcyjno-magazynujące, optymalny harmonogram.

Introduction

Under the condition that energy crisis and environmental problems increase seriously, more and more renewable energy sources are utilized in the form of distributed power generation or centralized power generation [1]. However, the intermittency and randomness of these renewable energy sources affect network's reliability and power quality, which runs counter to high reliability of smart grid. Hence, more flexible mode of operation and adequate backup power supply are required to enhance reliability of network. These requirements prompt large-scale application of DESS, leading DESS turn into an integral part of smart grid.

The interconnection of DESS provides ancillary services for electrical network, such as peak load regulation, renewable energy storage etc. [2-4] Renewable energy plants are connected to the grid massively in the form of energy storage station, by this means fluctuating power is restrained and a smoother [5,6] and satisfactory output curve can be obtained during a long period [7].. Regarding the power quality problems caused by large wind plant's gird-connection, e.g. voltage flicker, voltage over-limitation, harmonics, STATCOM is utilized along with DESS to eliminate these ill effects [8]. Energy storage systems with high energy density can provide temporal high power input in network's critical moment, saving time for operators to take action to prevent widespread blackout. Energy storage systems are connected to distribution network or micro grid in DESS pattern. High energy density DESS can regulate peak load, decrease cost of distribution network upgrade and serve as backup power supply to provide load transfer capacity, enhancing the reliability of distribution network. Through combination of high energy density DESS and high power density DESS, islanded micro grid can meet the requirements of balancing energy demand and restraining load fluctuation. [9]

These ancillary services are implemented on the basis of grid connected energy storage system's supply & storage capability which are decided by DESS's own electrical parameters and various electrical network restriction, such as rated power, short-term maximum power, rated capacity, circuit rated capacity, node voltage, grid topology and so on. The previous papers basically ponder over the restrictions controlled by DESS's own electrical parameters. However, the restrictions of connected grid is frequently ignored or not clearly stated. In addition, DESS is often connected to existing distribution lines which indicates that restrictions of connected grid will have a significant influence on DESS's supply & storage capability. [10]

Therefore, from general characteristic of electrical network and DESS, this paper proposes the conception of DESS supply & storage capability as well as its calculation methodology, comprehensively considering the constraint of connected electrical network and DESS. Under the context of optimal economic scheduling, the optimal scheduling strategy is worked out by applying DESS power supply & storage capability index. During the application, we propose target function with optimal economic benefit through analysing peak-valley price profit and line-loss change cause by peak regulation. Furthermore, mathematical expression of N-1 constraint and DESS power supply capability's effect on this expression are set as restriction condition for optimal economic scheduling model. Finally, taking practical distribution line as calculation example, solve the optimal economic scheduling strategy using genetic algorithm.

1. DESS supply & storage capability index

Supply & storage capability means the maximum discharge power and maximum charge power over a period of time, meeting all the constraint of the network and the DESS in the power supply region.

The establishment of supply & storage capability index is aimed at quantifying DESS's charge discharge ability at some point. The dispatcher can regulate and optimize DESS's charge discharge strategy on the basis of supply & storage capability index and load forecasting.

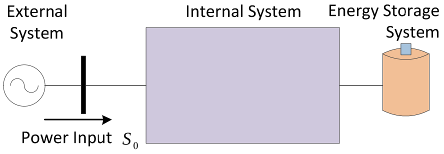


Fig. 1. Diagram of Equivalent Structure of the Grid

If we divide power supply area into external system, internal system and energy storage system, shown in Fig.1, then supply & storage capability index reflects DESS's ability of absorbing or weakening input power S_0 (aka. absorbed power of internal system) from external system.

If intermittent energy is connected to distribution network, such as wind power, photovoltaic power, the supply & storage capability index can measure DESS's ability to restrain output volatility. Residual energy of energy storage system at time $T+1$ can be expressed as:

(1) $$E(T+1) = E(T) + \alpha \int_T^{T+1} \left[P^c(g)\mu \right] dt - (1-\alpha) \int_T^{T+1} \left[P^d(g)/\eta \right] dt$$

In this formula, $E(T)$ is residual energy at time T, μ is DESS's charge conversion efficiency, η is DESS's discharge conversion efficiency. α is the charge discharge status, whose value range is 0 or 1. When α equals to 0, DESS is in discharge state; when α equals to 1, DESS is in charge state. $P^c(g)$ is the absorbed power from network. $P^d(g)$ is the supplied power from DESS.

DESS's charge discharge power $P^c(g)$, $P^d(g)$ should be subject to network restrictions such as line current and node voltage etc. Here, $g \in G$, G is solution space satisfied with network restriction.

In actual operation, $P^c(g)$, $P^d(g)$ generally mean rated charge discharge power ratio, which can be adjusted by energy storage system's charge discharge ratio. Supposing $k^c(g)$, $k^d(g)$ are DESS's charge discharge ratio and they are stable during one time step, then the previous formula can be simplified as:

(2) $$E(T+1) = E(T) + \alpha k^c(g) P^{cr} \eta - (1-\alpha) k^d(g) P^{dr} / \eta$$

Here, P^{cr}, P^{dr} are rated charge discharge power. Supposing $P^{d\max}(g,T)$, $k^{d\max}(g,T)$ are DESS supply capability indicator and corresponding discharge ratio, then DESS's restriction during discharge state can be described as below:

(3) $$\begin{cases} E(T) - k^{d\max}(g,T) P^{dr} / \eta \geq E_{\min} \\ k^{d\max}(g,T) P^{dr} \leq P^{dr\max} \end{cases}$$

Here, P^{dr} is DESS's rated discharge power, $E_{\min}$ is the lowest permissible residual energy, $P^{dr\max}$ is the maximum rated discharge power under the condition of maximum rated discharge ratio. DESS supply capability indicator can be derived from formula (3):

(4) $$P^{d\max} = k^{d\max} \cdot P^{dr}, \quad k^{d\max} = \min\left[\frac{P^{dr\max}}{P^{dr}}, \frac{E(T) - E_{\min}}{P^{dr}} \cdot \eta, k^d(g,T) \right]$$

Similarly, DESS's storage capability indicator is:

(5) $$P^{c\max} = k^{c\max} \cdot P^{cr}, \quad k^{c\max} = \min\left[\frac{P^{cr\max}}{P^{cr}}, \frac{E_{\max} - E(T)}{P^{cr} \cdot \eta}, k^c(g,T) \right]$$

Here, P^{cr} is DESS's rated charge power, $P^{cr\max}$ is the maximum rated discharge power under the condition of maximum rated discharge ratio. $E_{\max}$ is the maximum residual energy and η is charge discharge efficiency.

For the network containing N energy storage systems, at any time T, the supply & storage capability index can be described as follows:

(6) $$\begin{cases} P_c(g,T) = \sum_{i=1}^{N} P_i^{c\max}(g,T) \\ P_d(g,T) = \sum_{i=1}^{N} P_i^{d\max}(g,T) \end{cases}$$

Here, $P_c(g,T)$, $P_d(T)$ are the maximum storage supply capability of this area.

According to definition of supply & storage capability index, at any time, DESS charge discharge power should less than its index. Furthermore, from formula (4) and formula (5), we can draw the conclusion that when residual energy is approaching the lower limit, DESS's supply capability decreases dramatically, while when residual energy is close to upper limit, DESS's storage capability decreases quickly. Hence, if we are aimed at enhancing reliability and the load transfer capacity of distribution network, DESS's supply capability index should be always larger than supply reliable demand. If focusing on restraining output volatility of intermittent energy, DESS's charge discharge power needs to be restrained in order to make sure that its supply & storage capability index is larger than set value.

2. Application of supply & storage capability index's in optimal economic operation

Through the analysis in sector 1, DESS supply & storage capability index is the quantitative description about maximum supply capability and storage capability, reflecting the restrictions of network and corresponding DESS. It can be applied in dispatch scheduling policy.

This paper analyzes DESS operation economic model and its computing method and converts reliability analysis of distribution network to the restriction of DESS's supply & storage capability. Then on the premise of distribution network's high reliability, supply & storage capability index's effectiveness is verified under the context of DESS optimum economic scheduling.

2.1. Economic benefit of peak-valley price

DESS produces economic benefit through the way charging during valley load and discharging during peak load. Its computing mode can be depicted as follows:

(7) $$B = c_h \cdot \Delta E \cdot \eta - c_l \cdot \frac{\Delta E}{\eta} = C_E \cdot \Delta E$$

Here, ΔE is residual energy variation during the process of charge discharge, η is energy storage system's charge discharge efficiency which is a function about energy storage cell's charge discharge depth. During the period from T to $T+\Delta T$, η can be simplified as a constant. c_h is electricity price during peak load, c_l is electricity price during valley load. $c_l \cdot \Delta E / \eta$ and $c_h \cdot \Delta E \cdot \eta$ represent charge cost during valley load and discharge profit during peak load. $C_E = c_h \cdot \eta - \frac{c_l}{\eta}$ is a constant which represents equivalent peak-valley price after taking DESS's charge discharge efficiency into consideration. During the process of charge discharge, ΔE can be formulated as follows:

(8) $$\Delta E = \int_T^{T+\Delta T} P_c \cdot \eta \cdot dt = \int_T^{T+\Delta T} \frac{P_d}{\eta} \cdot dt$$

Generally in one time step, DESS charge discharge efficiency remains stable, so formula (8) can be simplified as:

(9) $\Delta E = P_c \cdot \eta \cdot \Delta T = \dfrac{P_d}{\eta} \cdot \Delta T$

The peak-valley price profit can be achieved after completing one charge discharge cycle, incurring cost during charge state and attaining benefits during discharge state. When measuring DESS charge discharge economic benefit at one point, we should think that charge during valley price will bring economic benefits. Therefore, divide peak-valley price profit equally in charge state and discharge state in order to balance the economic benefit of DESS. Furthermore, if DESS is charge during peak load or discharge during valley load, peak-valley price profit should be a negative value. Then DESS peak-valley price profit can be expressed as:

(10) $$B_P = \begin{cases} \dfrac{C_E}{2}(-1)^{\beta} \cdot P_c \cdot \eta \cdot \Delta T & P_c > 0 \\ \dfrac{C_E}{2}(-1)^{1-\beta} \cdot \dfrac{P_d}{\eta} \cdot \Delta T & P_d > 0 \end{cases}$$

C_E is equivalent peak-valley price, P_c, P_d are charge discharge power of DESS. β is electricity price state whose value range is 0 or 1, if β equals to 0, it means valley price, while β equals to 1, it means peak price.

From formula (10) B_P is negative if DESS is charge during peak load or discharge during load valley, causing penalty to target function which inclines scheduling strategy to charge during load valley and discharge during peak load. Meanwhile, because of continuum of peak-valley price, energy storage system will not frequently switch states, which extends energy storage cell's life span to some degrees.

If we describe the charge discharge power in formula (3) as charge discharge ratio, then DESS's peak-valley price is shown as follows:

(11) $$B_P = \begin{cases} \dfrac{C_E}{2}(-1)^{\beta} \cdot k_c \cdot P_{cR} \cdot \eta \cdot \Delta T & P_c > 0 \\ \dfrac{C_E}{2}(-1)^{1-\beta} \cdot \dfrac{k_d \cdot P_{dR}}{\eta} \cdot \Delta T & P_d > 0 \end{cases}$$

DESS's charge discharge power should satisfy the restriction of DESS supply & storage capability index when calculating peak-valley price of DESS.

(12) $$\begin{cases} k_c(T) \cdot P_{cR} \le P^{c\max}(g,T) \\ k_d(T) \cdot P_{dR} \le P^{d\max}(g,T) \end{cases}$$

2.2. Economic benefit by decreasing line loss

When DESS is charge during valley load, feeder current and line loss increase. When DESS is discharge during peak load, feeder current and line loss decrease. As a whole, discharge during peak load and charge during valley load smooth the load curve and decrease distribution network's total loss in 24 hours of one period.

Considering charge discharge power and distribution network load power as constant values during T to $T + \Delta T$, the economic profit by decreasing line losses of DESS can be depicted as follows:

(13) $$B_L = \left[\beta c_h + (1-\beta) c_l\right] \cdot (P_{0Loss} - P_{SLoss}) \cdot \Delta T$$

Here, β, c_h, c_l have the same meaning in formula (x), P_{0Loss} is the distribution network loss without DESS, P_{SLoss} represents the network loss after connecting DESS, both P_{0Loss} and P_{SLoss} are obtained by power flow calculation.

During the charge state, $B_L < 0$, and during discharge state $B_L > 0$. Taking 24 hours as a cycle, the sum of discharge state's profit and charge state's profit is the total economic profit by decreasing line losses in 24 hours.

2.3. Distribution network's Power Supply Reliability

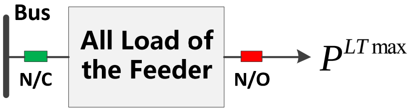
Distribution network runs in open loop and its primary network frame generally is a hand in hand closed-loop structure with multiple distribution lines. When a fault occurs in one distribution line, loop switches' states are changed to recover power supply for lost load. It is an important basis for distribution network planning that the network needs to satisfy N-1 load transfer restriction. As load grows, each line's load rate is increasing, leading to the result that the actual operated lines no longer accord with N-1 restriction.

As the interconnection of DESS, the power supply capability improves the network's load transfer capacity effectively. When a fault occurs in distribution network, energy storage system will discharge in rated power. The supply capability indicator of DESS can measure the load transfer capacity offered by DESS.

A single distribution line's maximum load transfer capacity in theory at time T can be formulized as follows:

(14) $$P^{LT\max}(T) = P^{RC} - P^{Load}(T)$$

Here, P^{RC} is line's rated capacity, $P^{Load}(T)$ is the total load of distribution line at time T, $P^{LT\max}(T)$ is distribution line's maximum load transfer capacity in theory.



However, in actual operation, because a distribution line is constrained by various factors, such as rated capacity, node voltage, etc, its actual load transfer capacity will always lower than maximum load transfer capacity in theory. Furthermore, distribution network cannot form electromagnetic loop network, this kind of topology constrain further increases distribution network's load transfer capacity, which is shown in Fig.3. The total load transfer capacity of line A and B is:

$$P^{LT} = \max\{P_A^{LT}, P_B^{LT}\} \neq P_A^{LT} + P_B^{LT}$$

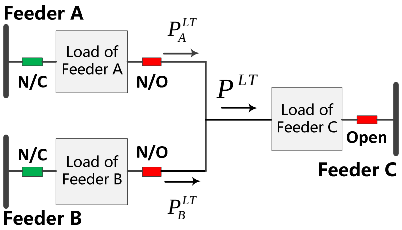


Fig. 2. Capacity of Load Transfer of Feeder A & B

In actual operation, record a single feeder's load transfer capacity as $P^{LT}(T,g)$, $g \in G$ considering all the restrictions of the network, where G is the solution space satisfied with all network restrictions.

Considering a distribution network with m interconnecting feeders and n DESS, line j with maximum load, if line j faults at time T, the total transfer capacity of distribution network is:

(15) $$P^{LTTotal}(T)=\sum_{i\le m,i\ne j}P_i^{LT}(T,g)+\sum_{i\le n}P_i^{d\max}(T,g)$$

Here, $P_i^{d\max}(T,g)$ is DESS i's supply capability at time T

(16) $$P^{LTTotal}(T)\ge P_{\max}^{Load}(T)$$

Here, $P_{\max}^{Load}(T)=P_j^{Load}(T)$, is the lost maximum load when a fault occurs in distribution network.

3. DESS optimal scheduling mode and its solution

3.1. DESS optimal scheduling mode considering power supply reliability

Section 2.1 to 2.2 analyzes peak-valley price profit and loss-decrease profit after DESS is connected to distribution network as well as the restriction of DESS's charge discharge power. Section 2.3 analyzes power supply capability's effect to distribution network's reliability, and then DESS power supply capability indicator is added to N-1 requirement. Therefore, DESS optimal scheduling model should compromise economic benefit and distribution network reliability.

Distribution network load and electricity price have the same characteristic that both are on a daily basis. Therefore, measuring DESS's economic benefit and distribution network's reliability should also be calculated in one complete cycle. During the process of DESS's scheduling strategy, taking its residual energy $E(T)$ at time T as a starting point and ΔT as a time step, calculate the supply & storage capability index in every time step in the next 24 hours, peak-valley price profit, loss-decrease profit and verify whether the results are subject to N-1 requirement or not.

The next 24 hours of load can be obtained by load forecasting or approximated by previous 24 hours or monthly, weekly load curve. In conclusion, for the distribution network with n DESS, the optimal scheduling model which takes distribution network reliability into consideration, can be formulated as follows:

(17) $$\max\quad B=B_L^{24h}+\sum_{i=1}^{n}B_{i,p}^{24h}$$

$$s.t.$$

(18) $$\begin{cases} k_i^c(T+j\Delta T)\cdot P_i^{cR}\le P_i^{c\max}(g,T+j\Delta T) & (a)\\ k_i^d(T+j\Delta T)\cdot P_i^{dR}\le P_i^{d\max}(g,T+j\Delta T) & (b)\\ P^T(T+j\Delta T)\ge P_{\max}^L(T+j\Delta T) & (c)\\ 0\le j\Delta T\le 24 & (d)\end{cases}$$

The target function consists of peak-valley price profit and line loss-decrease profit of each energy storage system in 24 hours.

(19) $$B_{i,p}^{24h}=\sum_{j=0}^{j\cdot\Delta T=24}B_{ip}(T+j\cdot\Delta T)$$

(20) $$B_L^{24h}=\sum_{j=0}^{j\cdot\Delta T=24}B_L(T+j\cdot\Delta T)$$

$B_{ip}(T+j\cdot\Delta T)$, $B_L(T+j\cdot\Delta T)$ are the profit from DESS i's peak-valley price profit and reduction loss profit in the j th time step which can be calculated by formula (11, 13).

Formula (18-a,b) are restrictions of power supply & storage capability index for each time step, namely DESS's charge discharge power is not more than its charge discharge capability. The DESS power supply & storage capability index is obtained by formula (4, 5), during whose calculation the restrictions about DESS rated power, residual energy, load flow, node voltage etc. are comprehensively considered. Formula (18-c) offers reliability constrains for distribution network, $P^T(T+j\Delta T)$ is calculated from formula (15), and formula (18-d) is time constraint limiting 24 hours from time T.

3.2. Solution for optimal scheduling mode

DESS optimal scheduling model's solution space are charge discharge power in each time step in a day whose values generally are multiples of rated charge discharge power rather than continuous. Therefore, we can discretize solution space. In consideration of transformer load measurements' time interval, adopt 1 hour as a time step.

Due to the complexity of target function and constraint condition, and the reality that they cannot be expressed in simple analytic expressions, we adopt genetic algorithm to solve and optimize the problem. Genetic algorithm is independent of target function's gradient information and realizes global searching, what's better it achieves optimal solution and is convenient to code in discrete solution space.

In genetic algorithm, matrix coding is utilized. The matrix element K_i^j represents DESS i's charge discharge coefficient in j th time step. The matrix's i th row vector $\begin{bmatrix}K_i^1 & K_i^2 & \cdots & K_i^{24}\end{bmatrix}$ means DESS i's charge discharge scheduling in 24 hours. The value range of K_i^j is:

(21) $$K_i^j\in\left\{-2,\frac{-3}{2},-1,\frac{-1}{2},0,\frac{1}{2},1,\frac{-3}{2},2\right\}$$

Respectively, DESS i's charge discharge power in j th time step is:

(22) $$P_i^j=\begin{cases}K_i^j\cdot P_i^{cR} & K_i^j>0\ \ \text{(charge)}\\ -K_i^j\cdot P_i^{dR} & K_i^j<0\ \ \text{(discharge)}\end{cases}$$

Through discretizing DESS charge discharge power and merging DESS charge discharge power with single variable K_i^j, DNA encoding length is decreased and algorithm convergence speed is accelerated.

Considering that optimal mode's target function value is quite big and individual function values are with minor differences, window method is utilized to select superior individual. Regarding to crossover, multi-point is adopted, crossover rate is 0.7. And for mutation, we also adopt multi-point whose mutation rate is 0.015. During the process of iterative evolution, calculate the similarity among all the individuals in the population and set it as the indicator of convergence degree to judge whether this iteration is convergent or not.

This paper utilizes standard genetic algorithm process and adds the procedure of restriction verification and DNA modification after individual crossover and mutation. The larger utilization ratio of DESS, its operation mode is closer to constraint boundary. Therefore, the DNA which doesn't pass restriction verification cannot be discarded arbitrarily. In this paper, we revise DNA by conducting crossover and mutation on parent-DNA until qualified individual comes into being.

4. Case study

Take one hand in hand distribution network in Shanghai as an example. The network includes two distribution lines where commercial, official, residential loads are in the majority, 28 distribution transformers, 2 DESS connected in feeder A's A node and B node. The topological connection is shown in Fig.4.

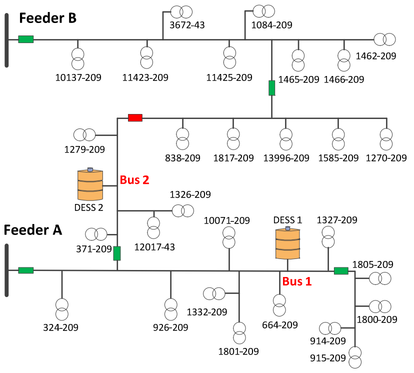


Fig. 3. Topological Connection of the feeders

Table 1. Electrical parameters of DESS.

name		DESS 1	DESS 2
rate capacity		80kW*8h	160kW*8h
rated power		80kW	160kW
maximum power		240kW	480kW
adjustable charge discharge power (kW)	code	charge discharge power	
	0	0	0
	0.5	40	80
	1.0	80	160
	1.5	120	240
	2.0	160	320

The parameters of energy storage system are shown in Tab 1. The distribution transformer load data in this example is peak load in 2010 summer. In this day, the valley price period lasts from 0:00 to 8:00, other period is peak price. The current time T equals to 2, and storage systems' residual energy is 240kWh, 400kWh respectively. Set the time step $\Delta T = 1$ and previous 24 hours' measurements as the distribution transformer load. We will conduct optimizing calculation on energy storage systems' charge discharge power in the next 24 hours.

The optimizing scheduling strategy obtained by solving DESS optimal scheduling model utilizing genetic algorithm and the contrast of feeder A's load before and after the interconnection of DESS are depicted in Fig.5. In this figure, DESS power is shown in right axis. Negative value indicates charge power, positive value indicates discharge power. Energy storage systems discharge with high power during heavy load period and charge during low load period in order to smooth the load curve and improve economical efficiency of distribution network to the utmost extent.

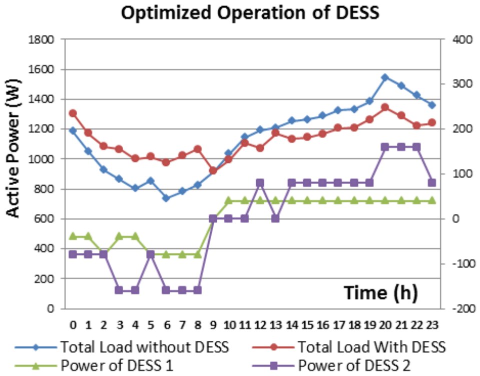


Fig. 4. Optimized Operation of DESS

Fig.6 shows total power supply & storage capacity index and total charge discharge power of DESS in 24 hours. Negative value represents charge power or storage capacity index. From this figure, we can see that DESS supply capability index stays low from 21:00 to 3:00 in the following day because of DESS's low residual energy. During this period, supply capacity index is determined by residual energy. In other period, network's constraints and DESS's maximum discharge power codetermine supply capability index.

DESS is close to full charge state from 7:00 to 18:00. Therefore, storage capacity index is mainly determined by DESS's spare capacity, leading to a low energy storage capacity. 20:00 to 22:00 is the peak load period, DESS storage capacity decreases because of node voltage restriction. As shown in Figure 5, in 24 hours, DESS's charge discharge power remains in the scope of supply & storage capacity of DESS from start to end, meeting supply & storage capacity restrictions of DESS (18-a, b).

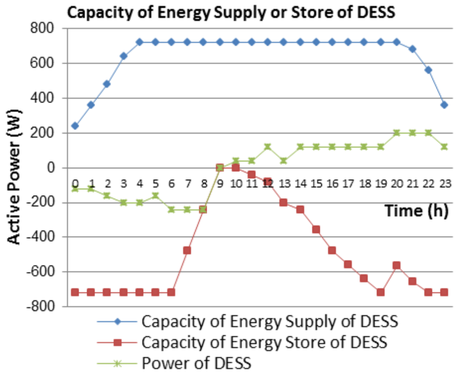


Fig. 5. Capacity of Energy Supply or Storage of DESS

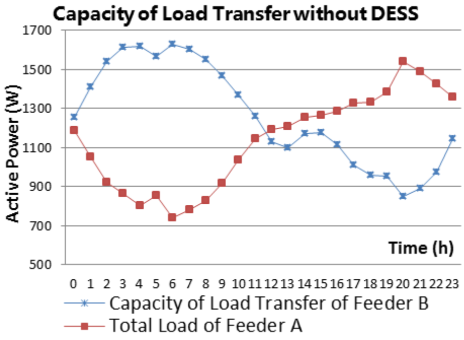


Fig. 6. Capacity of Load Transfer without DESS

Because DESS are all connected in feeder A, their scheduling mode has no effect on feeder B under normal operation mode. Feeder B plays a role of providing load transfer capacity when feeder A is failed to work. In this example, the rated capacity of feeder B is 2400kW, and the maximum load transfer capacity provided by feeder B without DESS connected to the network is shown in Fig.7. As load increases, the available maximum load transfer capacity provided by B decreases, even less than feeder A's load from 12:00 to 23:00 during peak load dissatisfied with N-1 restriction.

After DESS is connected to feeder A, its supply capability provides backup load transfer capacity for distribution network. The total load transfer capacity of DESS and feeder B is shown in Fig.8. By comparing the lost load in feeder A and the maximum load transfer capacity provided by DESS, we can draw a conclusion that feeder A and B satisfy the N-1 restriction.

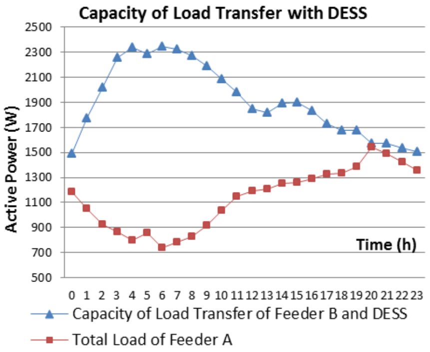


Fig. 7. Capacity of Load Transfer with DESS

5. Conclusion

Considering DESS's rated power, rated capacity, maximum discharge ratio and electrical network's various restrictions, this paper proposes the concept of power supply & storage capability index of DESS, which quantitatively describes the maximum power supply capacity and the maximum storage capacity of DESS. Power supply & storage capability index can be applied in operation optimization, volatility suppression ability calculation of intermittent energy in DESS.

The optimal economic scheduling results show the effectiveness of the application of the supply & storage capability index.

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