Energy Management Strategy of AC/DC Hybrid Microgrid Based on Solid-State Transformer

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ABSTRACT Voltage fluctuation and power mismatch which are caused by the decentralization, randomness, and intermittence of distributed energy resource along with load variability cause severe impacts on the security and quality of power network operation. Aiming at alleviating this issue, the structure of an AC/DC hybrid microgrid based on solid-state transformer is presented in this paper. A proper control coordination is developed to guarantee stable and reliable operation of the system. An energy management strategy is proposed to coordinate the power flow among the solid-state transformer, AC microgrid, DC microgrid and energy storage and to effectively suppress the fluctuation of the DC bus voltage. A novel adaptive droop control for the energy storage is proposed to prolong the supercapacitor life and achieve an optimum economic benefit to consumers. The droop coefficient is obtained by fuzzy logic controller of which the state of charge of the supercapacitor and unit-time electricity charge are assumed to be the input parameters. Simulation attest the feasibility of the proposed control coordination and energy management strategy.

INDEX TERMS AC/DC hybrid microgrid, energy management strategy, energy storage, droop control, solid-state transformer.

I. INTRODUCTION
The day-by-day increase in the global energy demand and the constraints on fossil fuels-based generation have encouraged worldwide nations to adopt more renewable distributed generations (DGs) into the electricity grids. However, the direct connection of DGs to the power grids may cause negative power quality impacts [1] including harmonic injection and voltage fluctuation. Microgrids are gaining more and more attention because of their high reliability and flexibility, which can provide a more effective way for DGs connection to distribution networks [2]. Based on the form of electric energy, microgrids can be categorized into DC, AC and AC/DC hybrid microgrids. DC and AC microgrids can only provide single form of electricity. On the other hand, AC/DC hybrid microgrid can better satisfy the demand of distributed renewable energy resources (DRER) access and the continuous increase of the DC loads [3], [4]. Meanwhile, multiform and high-reliable power grid has become essential to satisfy the demands of power consumers, which is difficult to achieve through traditional distribution networks [5]. In order to tackle the above objectives, the concept of energy router (ER) is proposed in the recent literatures [6]–[8].

Solid-state transformer (SST), also known as power electronic transformer (PET), not only has the same functions of traditional power transformer, but also can perform the following tasks:
1. Realizing electrical isolation and power transmission;
2. Providing a variety of power interface;
3. Realizing flexible operation of AC/DC hybrid system;
4. Improving node autonomy in distribution networks.

A comprehensive overview on SST is presented in [1], [2] including concepts, topologies, classification, power converters, material selection, and key aspects for design criteria and control schemes. Topology and control of household energy routers based on direct AC/AC power electronic transformer is proposed in [3]. While this approach can increase the power density and reliability of the device to some extent, it does not comprise a DC link, which calls for additional converters for DC loads. An overview of control strategies and power
management schemes for hybrid AC/DC microgrid is proposed in [4]. A new method to control the power and DC bus voltage is proposed in [5], but the control of AC bus is not considered. A DC bus voltage droop control strategy based on SST and energy storage unit is presented in [8]. Conventional droop control, which mimics the behavior of a synchronous generator in the power systems to modulate active and reactive powers by respectively regulating the frequency and voltage magnitude, is widely utilized to coordinate parallel inverters. The droop coefficients are usually determined by the maximum allowed frequency and voltage deviation along with the rated power capacity of each DG. In conventional droop control, the droop coefficient is fixed. Adaptive droop control method is proposed in [9]–[12] to facilitate dynamic change to the droop coefficient based on the variations of system operation conditions such as DG power generation, state of charge (SOC) of battery storage units or changes of adaptive proportion-integral (PI) control parameters. However, the electricity price (EP), which is a key parameter, is neglected in the proposed adaptive droop control design in the above-mentioned references. To satisfy the power consumers in ER-based low-voltage distribution networks and to achieve maximum economic benefits, EP should be considered. A novel active power control strategy for the converters based on the bidirectional droop characteristic is proposed in [13]–[15] to realize power balance and independent power sharing. But the proposed converter to connect the DC and the AC microgrids is a conventional AC/DC bidirectional converter that does not comprise the multiple functions of the SST. For the energy management strategy of hybrid energy systems, references [16], [17] propose the utilization of fuzzy logic to achieve multi-control objectives. SST is the core piece of equipment for building future ER and flexible distribution power systems [10], [11].

The above discussion show that most of the existing research have focused on developing some specific microgrids and SST topologies [18] and new power devices and modulation strategies [19]. However, not much attention has been given to energy management strategies for SST within AC/DC hybrid microgrids. Therefore, the main contribution of this paper can be summarized as follows:

1. The structure of an AC/DC hybrid microgrid based on SST is presented, and the control coordination strategy of each part is developed.

2. In contrary to the fixed droop coefficient in conventional droop control systems, a novel adaptive droop control approach is proposed in this paper.

3. An energy management strategy is proposed to prolong the life of supercapacitors and optimize economic benefits for power consumers.

The remaining sections of the paper are organized as below:

Section II introduces the structure of SST and the control method of its components. The structure and control of each sub-unit of the hybrid AC-DC microgrid are presented in section III. Section IV presents the proposed energy management strategy of the AC/DC hybrid microgrid based on SST. Simulation results are presented in section V while the key conclusions are drawn in section VI.

II. SST STRUCTURE AND CONTROL

The SST consists of a cascaded H-bridge (CHB) AC/DC rectifier, a dual active bridge (DAB) converter with a high frequency transformer and a DC/AC inverter as shown in Fig. 1.

A. CONTROL OF THE RECTIFIER STAGE

Rectifier stage, also known as the input stage, consists of three cascaded H-bridges with a DC bus reference voltage of 4kV. The state equations of the rectifier can be written as:

\[
\begin{align*}
L_s \frac{di_s}{dt} &= 3U_{hdc}d - U_s - R_i s \\
C_i \frac{dU_{hdc}}{dt} &= -di_s - \frac{U_{hdc}}{R_L}
\end{align*}
\]

where, \(i_s\) is the input side current, \(U_s\) is the input voltage, \(R_i\) is the input line resistance, \(L_s\) is the input inductor, \(U_{hdc}\) is the DC bus voltage, \(C_i\) is the rectifier DC bus capacitor, \(d\) is the rectifier pulse width modulation (PWM) duty cycle, \(R_L\) is equivalent load resistance of cascaded modules.

The single-phase d-q vector control is used in the rectifier control. First an imaginary phase which is 90 degree lagging the original phase is hypothesized. There are various methods to obtain the imaginary phase, such as: delay method, all-pass filter method (APF), and second-order generalized integrator (SOGI). Comparing the performance of APF, SOGI and the delay method, the APF response is found to be faster, so the APF method is adopted in this paper to obtain the imaginary phase. The transfer function \(G(s)\) of the APF in s-domain is as follows:

\[
G(s) = \frac{\omega - s}{\omega + s}
\]

where, \(\omega = 2\pi f\) is the angular frequency in rad/sec.

The relationship between the imaginary phase and the original phase (current and voltage) in \(\alpha-\beta\) reference frame is given by (3) and (4).

\[
\begin{align*}
I_\alpha &= I_s = I_s \cos(\omega t) \\
I_\beta &= I_s \sin(\omega t) \\
U_\alpha &= U_s = \sqrt{2} U \cos(\omega t) \\
U_\beta &= \sqrt{2} U \sin(\omega t)
\end{align*}
\]

The single-phase d-q transformation as given by (5) is applied to (3) and (4), to derive the d-q differential equations of the single-phase H-bridge rectifier as given by (6).

\[
[x]_{dq} = [T] [x]_{\alpha\beta}
\]
where, \( T = \begin{bmatrix} \sin(\omega) & -\cos(\omega) \\ \cos(\omega) & \sin(\omega) \end{bmatrix} \)

\[
\frac{d}{dt} \begin{bmatrix} i_d \\ i_q \end{bmatrix} = \frac{3U_{hdc}}{L_s} \begin{bmatrix} d_\alpha \\ d_\beta \end{bmatrix} - \frac{1}{L_s} U_{sd} \begin{bmatrix} i_d \\ i_q \end{bmatrix} \]

\[
- \frac{1}{L_s} \begin{bmatrix} R_s & -\omega \\ \omega & R_s \end{bmatrix} \begin{bmatrix} i_d \\ i_q \end{bmatrix} \]

\[
- U_{hdc} \begin{bmatrix} i_d \\ i_q \end{bmatrix} \]

\[
\frac{dU_{hdc}}{dt} = -\frac{1}{2C} \begin{bmatrix} d_\alpha \\ d_\beta \end{bmatrix}^T \begin{bmatrix} i_d \\ i_q \end{bmatrix} - U_{hdc} \frac{R_s}{L_s} \frac{d_\alpha}{C} \]

The input-stage control objective is the realization of unity power factor operation along with a balanced input-stage-side DC-link voltage. Figs. 2 and 3 depict the input-stage single-phase decoupled current control and input-stage balancing control, respectively.

In Fig. 2, the reactive current reference \( i_{sq}^* \) is set to 0 in order to obtain unity power factor. The active current reference \( i_{sd}^* \) is adjusted by the voltage loop PI controller according to the voltage error between the input-stage DC-link capacitor voltage reference \( U_{dc-ref} \) and the average value \( U_{dc-ave} \) of all input-stage DC-link capacitor voltages. For DC-link voltage balancing problem, a voltage equalization controller is used. Detailed modeling of this controller can be found in [8].

**B. CONTROL OF THE DAB**

The dual active bridge consists of a high voltage H-Bridge, a high frequency transformer (HFT) and a low voltage H-bridge. By adjusting the phase-shift between the primary side H-bridge and the secondary side H-bridge, the power transferred by DAB (P) converter can be determined by (7).

\[
P = \frac{U_{hdc}U_{ldc}}{4Lf} d_{dc}(1 - d_{dc}) \]  

A single-phase shift control is used for the control of the DAB, as shown in the block diagram of Fig. 4. In this method,
the difference between the low DC voltage \( U_{dc} \) and the reference voltage is used as an input signal to a PI controller. The phase shift angle is adjusted by the PI controller to regulate \( U_{dc} \) according to this voltage error. The reference voltage is obtained from the power-voltage droop control equation given by (8).

\[
U_{ldc}^* = U_{ldcn} + k_d(P_{net} - P_0) \quad (8)
\]

where, \( U_{ldcn} \) is the rated value of the low voltage DC bus, \( k_d \) is the droop coefficient.

C. CONTROL OF THE INVERTER STAGE

In the inverter stage, also known as the output stage, the DC link voltage is regulated by the DAB converter while the PWM AC inverter controls the magnitude of the output side AC voltage. The inverter controller has an inner current loop and an outer voltage loop as shown in Fig. 5. A proportional-resonant (PR) controller is used to guarantee high tracking performance.

A maximum power point tracking (MPPT) control algorithm employs the improved variable step perturb and observation (P&O) method [20]. The working principle is based on the slope of the P–V curve of the PV panel. The operating voltage is perturbed depending on the nature of the slope to track the maximum power point.

B. ENERGY STORAGE BIDIRECTIONAL DC/DC CONVERTER

Energy storage (ES) devices are used for balancing the power in grid-connected mode and can support the regular operation of the AC/DC hybrid microgrid in islanded mode. Due to the intermittency of renewable energy sources, ES has become essential for microgrids of DGs. In this paper, a bidirectional buck-boost converter [21] is used as the charging and discharging circuit for the ES device and the supercapacitor, which is a fast charging/discharging device. There are different control objectives for ES system in grid-connected and islanded modes, and the bidirectional power flow is achieved by controlling the ES inductor voltage. Topology and control of the ES are shown in Fig. 7.
In grid-connected mode, an adaptive droop control is proposed in this paper. The droop coefficient is obtained through energy management strategy. Closed-loop control of the ES inductor current is employed, and the ES charging/discharging current reference value is obtained by the droop control. The voltage-current droop characteristic of the ES system is shown in Fig. 8.

![Voltage-current droop characteristic of the ES system.](image)

In Fig. 8, \( m_{ES} \) is the initial droop coefficient, \( I_{ESmax} \) and \(-I_{ESmax}\) are the maximum values of the supercapacitor discharge and charge currents, respectively; with a range of \([-30A, 30A]\). \( U_{L1} \) and \( U_{H1} \) are action thresholds, which are set to reduce the frequency of supercapacitor charging and discharging and to improve supercapacitor life and system efficiency. Usually, the DC bus voltage is 750V when the supercapacitor has no output power. When the bus voltage reaches its minimum value, the supercapacitor generates a maximum current, which is the 30A in this study. Based on these two points, the droop slope can be determined.

In islanded mode, ES system replaces the grid-connected part to maintain the low voltage DC bus at rated value and the controller includes the outer DC voltage loop and inner ES inductor current loop as shown in Fig. 7.

### IV. ENERGY MANAGEMENT STRATEGY

In this section, the power flows in the grid-connected mode is discussed, and an energy management strategy for the grid-connected mode is proposed.

![Power flows in grid-connected mode.](image)

The possible power flows of SST in grid-connected mode are as shown in Fig. 9. Thus, the active power balance equation in grid-connected mode can be expressed as:

\[
P_{DG} + P_{G} + P_{ES} - P_{load} = 0 \tag{11}
\]

where, \( P_{G} \) is the grid side power, \( P_{ES} \) is the ES power, \( P_{load} \) is the DC and AC load power, \( P_{DG} \) is the distributed generation, including \( P_{PV} \) and \( P_{AC} \).

Taking \( P_{net} = P_{DG} - P_{load} \) as the net output power of the hybrid AC/DC microgrid; If \( P_{net} < 0 \), the ES and distribution network are required to compensate the deficient power. On the other hand, if \( P_{net} > 0 \), there exists surplus power to charge the supercapacitor and inflow the distribution network. Equation (11) can be simplified as:

\[
P_{net} + P_{G} + P_{ES} = 0 \tag{12}
\]

In islanding mode, \( P_{G} = 0 \), so the power balance equation can then be expressed as:

\[
P_{net} + P_{ES} = 0 \tag{13}
\]

From the above power flow situation, in the grid connected mode, the power flow between the distribution network, ES and hybrid AC/DC microgrid is required when \( P_{net} \neq 0 \). Power distribution problems can occur, and if power distribution is not satisfactory, supercapacitor life and economy of consumers can be affected. Therefore, it is necessary to set a reliable energy management strategy to distribute electricity rationally.

An energy management strategy is proposed in this paper, which considers the impact of SOC capacity for supercapacitor life and the impact of electricity price for economic customers. The strategy can smoothen the fluctuations of renewable energy output power and load demand.

According to the above discussion, the regulation of the droop coefficient will depend on three factors: SOC, EP and \( P_{net} \). It is suitable to use fuzzy control for the energy management strategy with multiple control objectives that are mutually restrictive. A fuzzy logic control (FLC) is based on fuzzy-logic thinking in the design of how a controller works. The fuzzy logic is meant to establish a buffer zone between the traditional zero and one, with logic segments of none-zero and none-one possibility. Therefore, a FLC is used to realize the novel adaptive droop control proposed in this paper. EP and \( P_{net} \) can be expressed by unit-time electricity charge \( EC_{unit} \). To ease the calculation, a normalized method is used to map EP and \( \pm P_{ES} \) to the range \([0, 1]\), then \( EC_{unit} \) can be expressed as:

\[
EC_{unit} = \frac{EP - EP_{min}}{EP_{max} - EP_{min}} \times \frac{P_{N} - P_{ES} - P_{net}}{2P_{N}} \tag{14}
\]

where, EP is the real-time electricity price, \( EP_{max} \) and \( EP_{min} \) are the maximum and lowest values of electricity price, respectively.

In the proposed FLC, SOC and \( EC_{unit} \) are set as the two input variables, while \( m_{ES} \) is set as the output variable. The
centroid method is utilized for defuzzification of fuzzy numbers. The ranges of SOC, \( EC_{\text{unit}} \) are set as in (15).

\[
\begin{align*}
SOC & \in [40\%, 80\%] \\
EC_{\text{unit}} & \in [0, 1]
\end{align*}
\]  
(15)

It should be noted that 40\% is greater than the minimum allowable threshold of SOC to ensure sufficient remaining capacity of ES to maintain the regular operation of the AC/DC hybrid microgrid when switching to islanded mode. The input and output membership functions of the FLC contain five grades as shown in Fig. 10. Five grades are employed to describe the input and output variables: L (low), SL (slightly low), M (medium), SH (slightly high), H (high).

![Membership functions of the input and output variables.](image)

It can be seen that before \( t = 0.5 \)s, the PV output power is 10kW, DC load power demand is 10kW, AC DG output power is 20kW, AC load power demand is 20kW. Initially, the DC bus voltage rapidly rises and stabilizes at 750V and 20638V.

### TABLE 1. Fuzzy rules of discharge.

| SOC    | \( m_{\text{ES}} \) | \( EC_{\text{unit}} \) |
|--------|----------------------|------------------------|
| L      | L                    | L                      |
| L      | L                    | L                      |
| M      | L                    | L                      |
| M      | M                    | M                      |
| M      | M                    | M                      |
| SH     | M                    | H                      |
| SH     | M                    | H                      |

### TABLE 2. Fuzzy rules of charge.

| \( m_{\text{ES}} \) | \( EC_{\text{unit}} \) |
|----------------------|------------------------|
| L                    | L                      |
| L                    | L                      |
| L                    | L                      |
| SL                   | M                      |
| M                    | M                      |
| M                    | M                      |
| SL                   | L                      |
| L                    | L                      |
| SL                   | L                      |
| L                    | L                      |
| L                    | L                      |

3) When \( P_{\text{net}} > 0 \), priority is given to deliver surplus power to the distribution grid for economic benefit.

4) When \( P_{\text{net}} < 0 \), the priority is given to supply power by ES to reduce customers’ electricity bills.

### V. SIMULATION RESULTS

In this section, the performance of the proposed energy management strategy is assessed through simulation analysis. The main parameters of the simulation model are listed in Table 3. The simulation analysis assumed two scenarios for the studied model: system with surplus power and system with power deficiency.

![Voltage and power variations of each unit within the hybrid microgrid.](image)

**TABLE 3. Simulation parameters.**

| Parameter                        | Value |
|----------------------------------|-------|
| Distribution grid voltage        | \( U_{\text{d}} = 10\text{kV} \) |
| MV DC-link voltage               | \( U_{\text{dc}} = 4000\text{V} \) |
| LV DC-link voltage               | \( U_{\text{dc}} = 750\text{V} \) |
| LV AC-link voltage               | \( U_{\text{ac}} = 220\text{V} \) |
| Switching frequency              | \( f_s = 10\text{kHz} \) |
| AC input inductance              | \( L_s = 18\text{mH} \) |
| MV DC-link Capacitance           | \( C_s = 3000\mu\text{F} \) |
| Rated ratio of HFT               | 40:9 |
| LV DC-link Capacitance           | \( C_s = 470\mu\text{F} \) |
| LC filter in LV AC part          | \( L_f = 1.5\text{mH}, C_f = 12\mu\text{F} \) |
| Rated PV capacity                | \( P_{\text{PV}} = 10\text{kW} \) |
| Rated supercapacitor voltage     | \( U_{\text{es}} = 600\text{V} \) |
| Filter inductance in ES part     | \( L_{\text{es}} = 5\text{mH} \) |
| Filter inductance in PV part     | \( L_{\text{pv}} = 0.4\text{mH} \) |

In case of surplus power, Table 4 shows the power variations within each module. Figs. 11 and 12 show the voltage and power variations of each unit within the hybrid microgrid. It can be seen that before \( t = 0.5\text{s} \), the PV output power is 10kW, DC load power demand is 10kW, AC DG output power is 20kW, AC load power demand is 20kW. Initially, the DC bus voltage rapidly rises and stabilizes at 750V and 20638V.
TABLE 4. Power variations in Case of surplus power.

| $t$ | $P_G$  | $P_{PS}$ | $P_{PV}$ | $P_{DC\_load}$ | $P_{DG}$ | $P_{AC\_load}$ |
|-----|--------|---------|---------|-----------------|---------|-----------------|
| 0-0.5s | 0kW   | 0kW   | 10kW   | 10kW           | 20kW    | 20kW            |
| 0.5-1s  | -10kW | -5kW  | 10kW   | 5kW            | 20kW    | 10kW            |
| 1-1.5s  | -24kW | -11kW | 10kW   | 5kW            | 30kW    | 10kW            |
| 1.5-2s  | -17kW | -8kW  | 10kW   | 5kW            | 30kW    | 10kW            |

FIGURE 11. Voltage and power variation profile of each unit in the DC microgrid.

The AC frequency is set at 50Hz, because the load demand and the power provided by the DGs are equal. Within the period $t = 0.5s$ and $t = 1s$, the DC load is reduced to 5kW and the AC load is reduced to 10kW. The power provided by the DGs is too much, and the distribution grid and energy storage system are needed to absorb the surplus energy. Within this period, the DC bus voltage raises rapidly and stabilizes at 765V due to the reduced DC load.

Between $t = 1s$ and $t = 1.5s$, the DG output power increases to 30kW and the DC bus voltage rises to 775V. The following conclusions can be obtained from the power distribution after two-time changes of load power: with different $P_{\text{net}}$, the power distribution ratios of energy storage and distribution network are different. This is because the energy management strategy proposed in this paper gets different droop coefficients with different $P_{\text{net}}$, which makes the power distribution of both not set at a fixed value to achieve optimal power distribution. At time $t = 1.5s$, the EP changes from 0.3 to 0.9. With the rise of EP, the power absorbed by the ES is decreasing while the power delivered to the distribution network is increasing. This indicates that when the electricity price is getting high, the surplus power is delivered to the distribution network as a priority to gain economic benefits to the consumers.

In the case of Power deficiency, Table 5 shows the power variations of each module. Figs. 13 and 14 show the voltage and power profiles of each unit within the hybrid microgrid. Before $t = 0.5s$, Balance is maintained within the AC/DC hybrid microgrid. Within the period $t = 0.5s$ and $t = 1s$, the DC load is increased to 15kW and the AC load is increased to 30kW. This indicates that when the electricity price is getting high, the surplus power is delivered to the distribution network as a priority to gain economic benefits to the consumers.
by the two parts can be obtained as follows: 8kW and 7kW; respectively.

**TABLE 5. Power variations in Case of deficiency power.**

| $t$  | $P_0$ | $P_{ES}$ | $P_{PV}$ | $P_{DC, load}$ | $P_{AC}$ | $P_{AC, load}$ |
|------|-------|----------|----------|----------------|---------|----------------|
| 0-0.5s | 0kW   | 0kW      | 10kW     | 10kW           | 20kW    | 20kW           |
| 0.5-1s  | 7kW   | 8kW      | 10kW     | 15kW           | 20kW    | 30kW           |
| 1-1.5s  | 11kW  | 14kW     | 10kW     | 25kW           | 20kW    | 30kW           |
| 1.5-2s  | 17kW  | 8kW      | 10kW     | 25kW           | 20kW    | 30kW           |

Within the period $t = 1 - 1.5s$, the DC load is raised to 25kW while the AC load remains unchanged, $P_{net} = -25kW$, the electricity price does not change at this time. The power provided by the two parts is: 14kW, 11kW. Since the electricity price is very high, EP = 0.9, the power provided by the ES has been greater than the power provided by the distribution network in order to reduce the electricity costs for customers. At time $t = 1.5s$, the EP changes from 0.9 to 0.3. As such, the power provided by the distribution grid and energy storage is changed because of the lower EP. The power provided by the distribution network becomes higher, 17kW, while the power provided by the ES becomes lower, 8kW. This is because lower EP allows more power to be obtained from the distribution grid, while avoiding over-discharging the supercapacitor which causes severe impacts to its operational life.

Fig. 15 shows a comparison of the performance of the proposed novel adaptive droop control and the conventional droop control in terms of the ES charge and discharge power. It can be observed that before $t = 0.5s$ there is no power flow in the ES unit because the power is kept balance among all sub-units during this period. Within the period 0.5-1s, compared with conventional control, the proposed control approach in this paper exhibits less power during charging and more power when discharging. During the period 1-1.5s, the proposed adaptive droop control can better regulate the power variation and prolong supercapacitor life upon changes in $P_{net}$. During the period $t = 1.5s$ and $t = 2s$, with the change of the EP, input or output power of the ES is reduced to improve economic benefits of power consumers. On the
distribution optimization.

The structure of an AC/DC hybrid microgrid based on SST is presented in this paper. An energy management strategy is proposed to resolve the issues of the fixed droop coefficient currently adopted in the conventional droop control systems. With such static coefficient, the power distribution cannot change with the change of the system operating conditions such as intermittency of renewable energy sources. A novel adaptive droop control method is proposed for the ES system to prolong supercapacitor operational life, and enhance the economic benefits of power consumers. The feasibility of the proposed energy management strategy is verified through in-depth simulation analysis. Compared with the conventional droop control system, simulation results reveal that the proposed controller comprises superior performance in power distribution optimization.

VI. CONCLUSION

The structure of an AC/DC hybrid microgrid based on SST is presented in this paper. An energy management strategy is proposed to resolve the issues of the fixed droop coefficient currently adopted in the conventional droop control systems. With such static coefficient, the power distribution cannot change with the change of the system operating conditions such as intermittency of renewable energy sources. A novel adaptive droop control method is proposed for the ES system to prolong supercapacitor operational life, and enhance the economic benefits of power consumers. The feasibility of the proposed energy management strategy is verified through in-depth simulation analysis. Compared with the conventional droop control system, simulation results reveal that the proposed controller comprises superior performance in power distribution optimization.

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