New Direction of Microgrid in China and Multi-DG Expansion Capacity Technique for a Nanogrid

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1.New Direction of Microgrid in China

1.1 China Energy Strategy-1

- Revolutionary strategy in Energy production and consumption (2016-2030). Issued by National Development and Reform Commission & National Energy Administration

I. 2020，Energy revolution arrangement startup

- Fossil energy will be substituted by clean energy ,
- Change the extensive growth status quo of energy,
- Pay equal attention to the industrial policy orientation and industrial constraint.

1.New Direction of Microgrid in China

1.1 China Energy Strategy-1

- Revolutionary strategy in Energy production and consumption (2016-2030). Issued by National Development and Reform Commission & National Energy Administration.

II. 2021-2030，fast growing uses of sustainable renewable energy, natural gas and nuclear energy , and significant reduction uses of high-carbon fossil fuels.

- Total energy consumption be controlled within 6 billion tons of standard coal,
- Non-fossil energy accounts for about 20% of the total energy consumption,
- Natural gas accounts for 15% of the total.

1.New Direction of Microgrid in China

1.1 China Energy Strategy-2

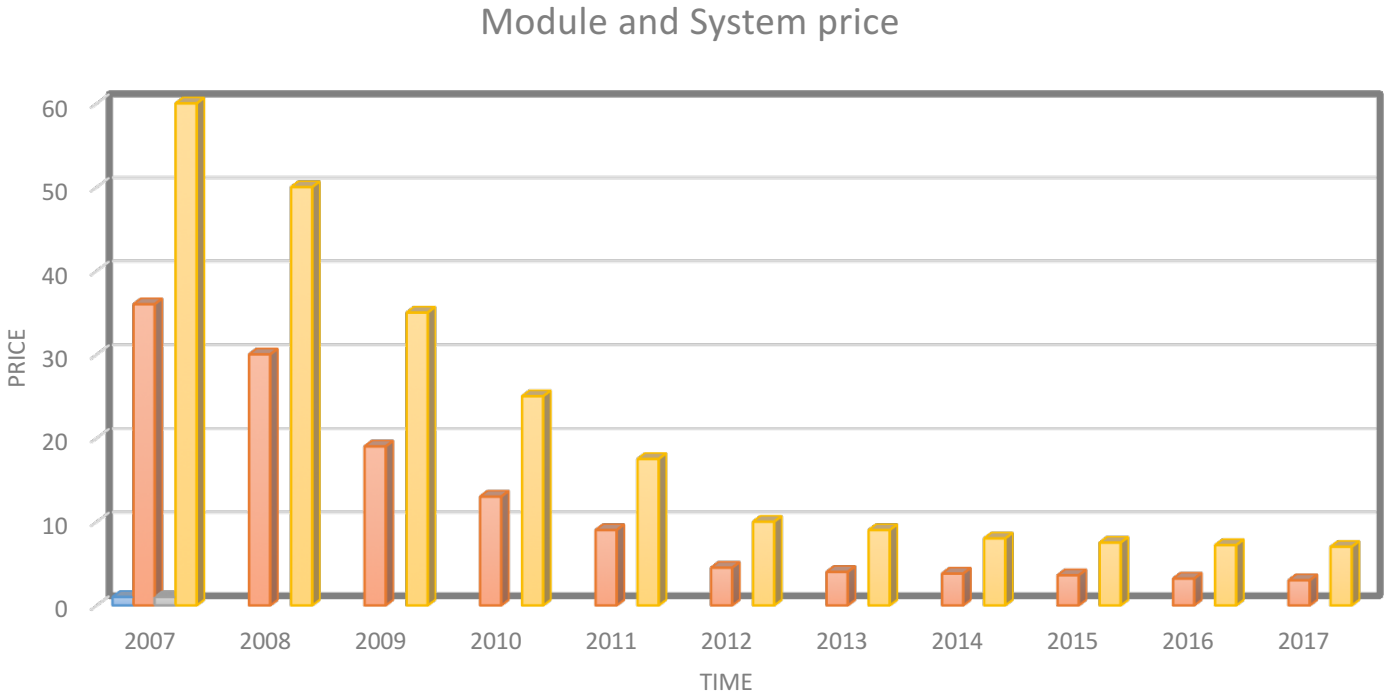
- Development and Reform Commission Energy Research Institute

- 2025, Energy consumption will peak ;
- 2050,the share of the new energy sources in energy consumption increase to 66%
- 2050, the share of electricity in terminal energy consumption increase to 62% ,
- 2050, 91% of the electricity comes from new energy sources

1.New Direction of Microgrid in China

1.2 The development of PV and abandoning PV

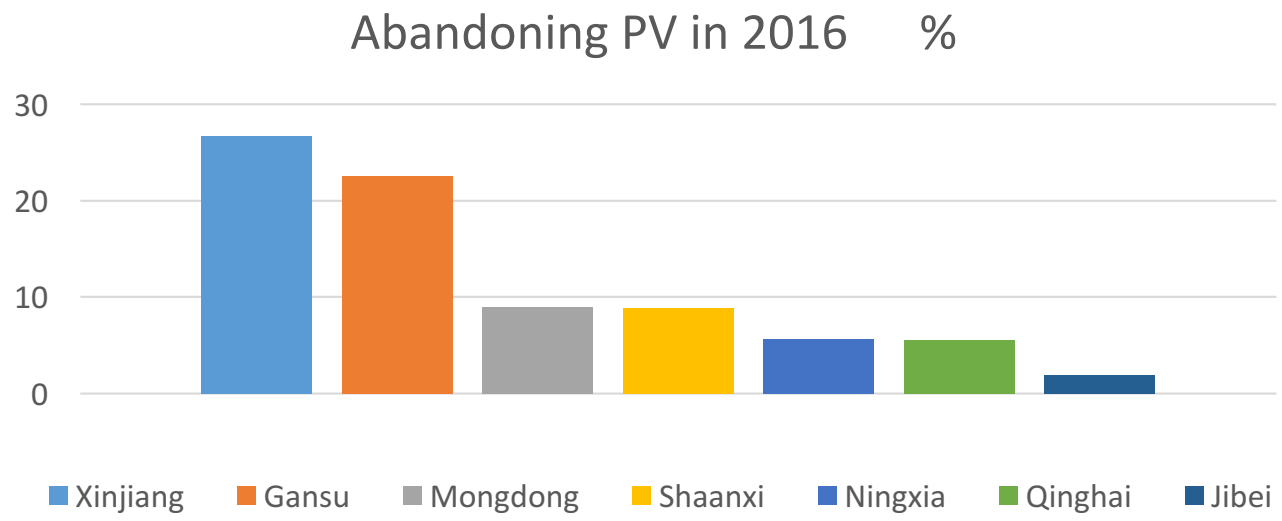
- 2012, the State Grid remove restrictions on the grid connected distributed PV.
- 2016, the new installed capacity of PV is 4.23GW
- 2017, the price of PV module decrease to 10% of 2007



1.New Direction of Microgrid in China

1.2 The development of PV and abandoning PV

- 2016, a total of 70.42 billion kwh of PV abandoned. The share is 19.81% in west north of China.
- the share of abandoning PV over 30% in Xinjiang and Gansu



1.New Direction of Microgrid in China

1.2 The development of PV and abandoning PV

- The real reason for abandoning PV and wind is not a technical issue but a barrier to the interests of all provinces.

By Wang Zhongying, deputy director of theNational Energy Research Institute

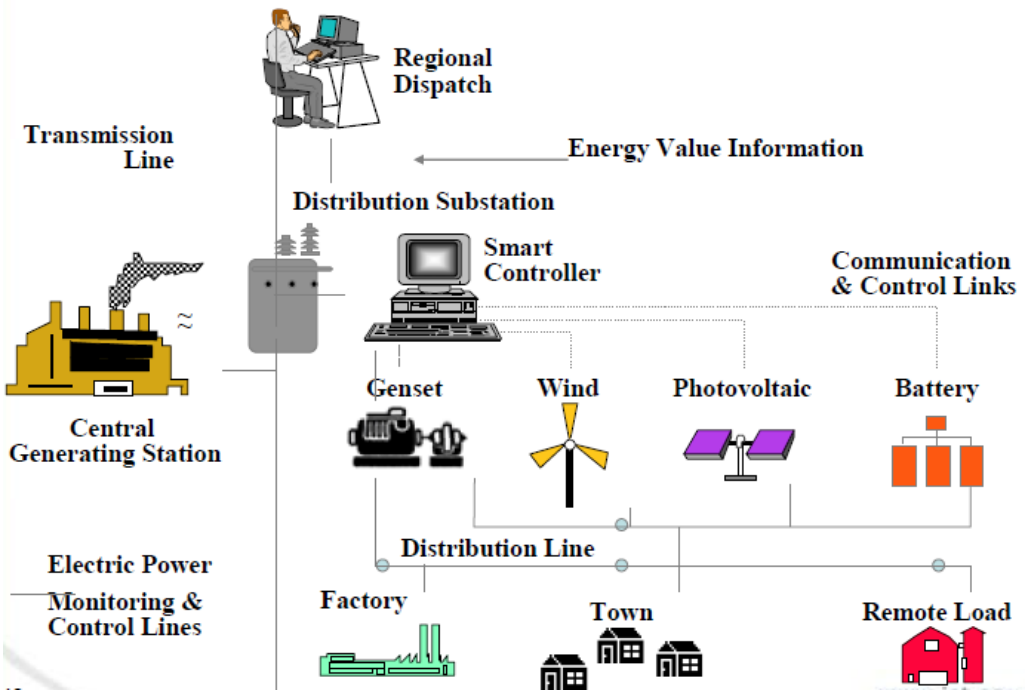
- The receive problem of renewable energy is largely linked to the regional blockade.

By Development and Reform Commission: Xu Jintao, vice president of the National Institute of Development of Peking University

1.New Direction of Microgrid in China

1.3 What is the best way at the problem?

- The trial measure for developing the grid connected microgrid.
  - Index of [2017] 1339 .
  - Issued by The national energy administration of the national development and reform commission (NDRC)



1.New Direction of Microgrid in China

1.3 What is the best way at the problem?

Ⅰ. Miniature . 35 kV and below, no more than 20 MW

Ⅱ. Cleaning. The total capacity of renewable energy is more than 50%, or the Integrated energy supply system efficiency of natural gas is more than 70%

Ⅲ.Autonomy. Guarantee the continuous power supply of important load (no less than 2 hours). The annual exchange capacity of electricity between the micro-grid and the external power grid is no more than 50% of the annual electricity consumption

Ⅳ. Friendly. The power exchanging and exchanging time between microgrid and the grid are controllable

1.New Direction of Microgrid in China

1.3 What is the best way at the problem?

- Part 23 The new energy projects in a microgrid can be incorporated in scope of subsidization of the renewable energy development fund.
- Part 24 Micro-grid projects are encouraged to be directly financed through the issuance of corporate bonds and other ways , and enjoy the green credit support.
- Part 25 the main operation of the micro-grid based on self-balancing microgrid self-declared reserve capacity, unified pay the corresponding reserve capacity costs.

Contents

2.A Nanogrid Based Microgrid

2.1 The features of the new police based microgrid

2.1.1 Cleaning.

- The power generation is mainly based on local renewable energy, or the comprehensive utilization of multi energy supply, such as natural gas, and encourages to utilize the new clean such as fuel cells.
- Among them, the installed capacity of renewable energy accounted for more than 50%, or natural gas multiple supply system's comprehensive energy efficiency achieved more than 70%.

2.A Nanogrid Based Microgrid

2.1 The features of the new police based microgrid

2.1.1 Cleaning.

- A gas turbine

efficiency	heat conversion / power generation
• coal	25-40% , 30-40%;
• Diesel	30-45%, 30-40%;
• Natural gas heating	55-65%, 35-55%.

2.A Nanogrid Based Microgrid

2.1 The features of the new police based microgrid

2.1.1 Cleaning .

- A gas turbine

➢Natural gas turbine installed capacity is generally 0.6-2 million kilowatts.

➢By energy cascade, the efficiency of natural gas turbine hybrid supply of cold, heat, electricity can reach more than 80%.

2.A Nanogrid Based Microgrid

2.1 The features of the new police based microgrid

2.1.2 Autonomy

- The microgrid can guarantee the electrical equipment operating independently.
- self-balancing between power supply and load
- black-start.
- In islanding mode, it can supply continuous to important loads (no less than 2 hours).
- The annual electricity exchange between the microgrid and the external grid is generally less than 50% of the annual electricity consumption.

2.A Nanogrid Based Microgrid

2.1 The features of the new police based microgrid

2.1.3 Friendly

- The exchange power and the exchange time between microgrid and external grid are controllable.
- It can realize backup, peak shaving, demand side response and other bidirectional services with the merged power grid.
- It can meet user's power quality requirements, and can achieve friendly interaction with the merged grid.
- UPC mode for microgrid

2.A Nanogrid Based Microgrid

2.1 The featur

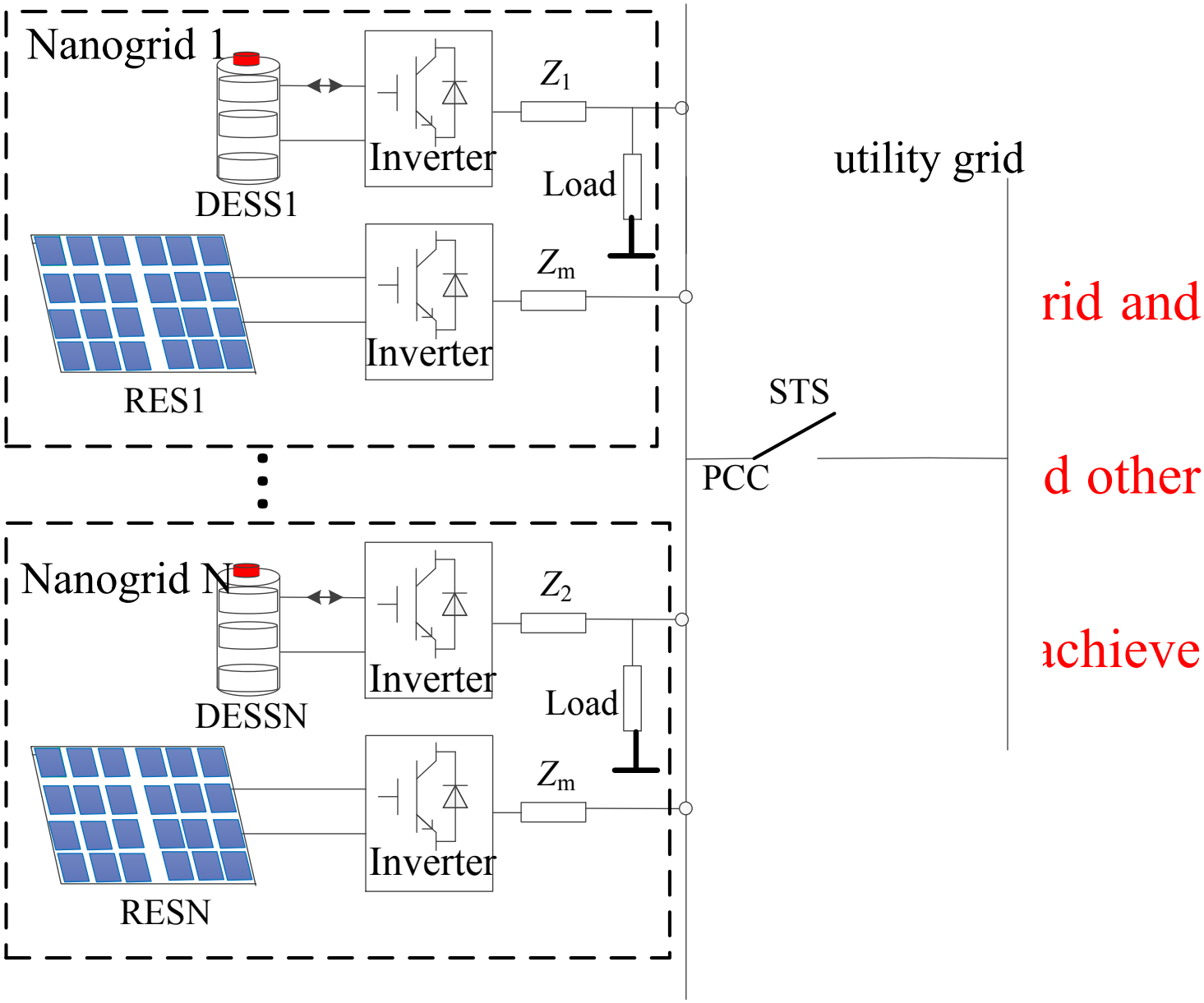
2.1.3 Friendly

➢The exchang rid and external grid

➢It can realize d other bidirectional

➢ It can meet achieve friendly intera

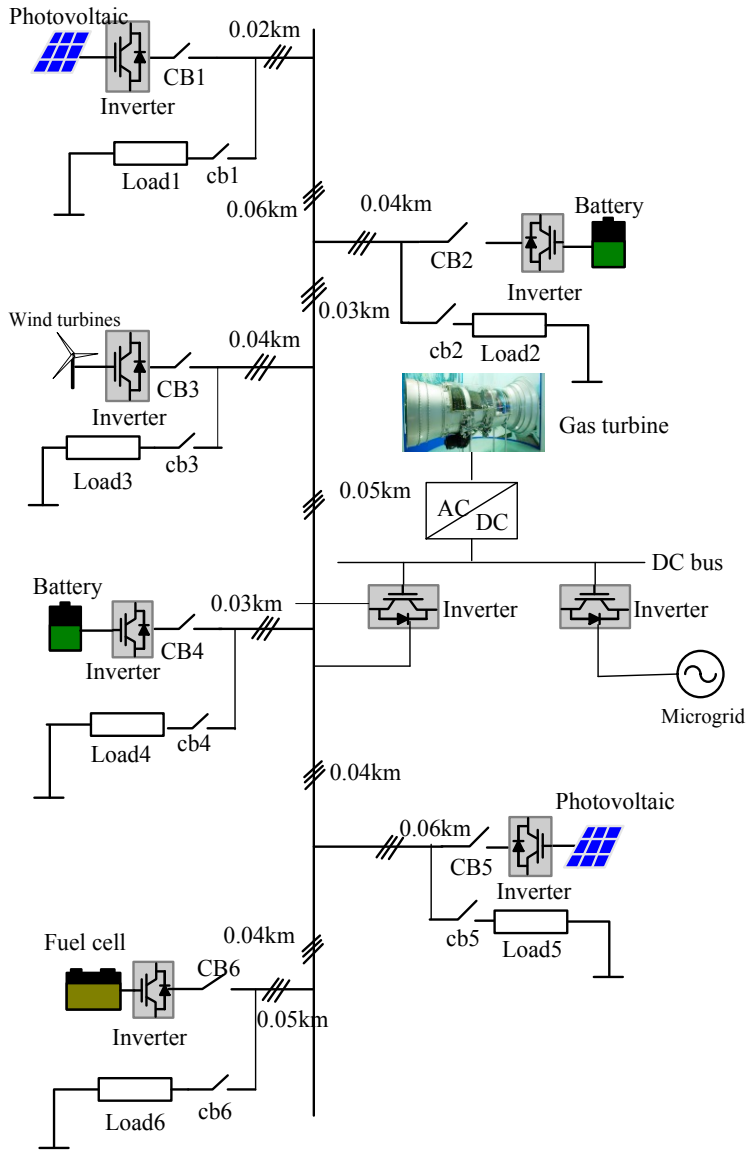
➢UPC mode f



2.A Nanogrid Based Microgrid

2.2 The multi-DG Expansion capacity based nanogrid

- The basic unit of the microgrid is nanogrid.
- the storage battery would be a household appliances and every home might be a basic unit of a nanogrid.
- Nanogrid acts as a basic trading settlement unit in microgrid. Every home acts as a basic trading settlement unit



2.A Nanogrid Based Microgrid

2.2 The multi-DG Expansion capacity based nanogrid

- The interface of the nanogrid to microgrid is power electronic converter.
- Frequency and voltage of the nanogrid can be adjusted independently.
- The client in the Narogrid has storage unit with plug & play features

2.A Nanogrid Based Microgrid

2.2 The multi-DG Expansion capacity based nanogrid

- Nanogrid acts as a basic trading settlement unit in microgrid. Every home acts as a basic trading settlement unit
- The interface of the nanogrid to microgrid is power electronic converter.
- A nanogrid also is a independent transaction settlement unit
- Frequency and voltage of the nanogrid can be adjusted independently.
- The client in the Narogrid has storage unit with plug & play features

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3.Decentralized SOC Balancing Strategy

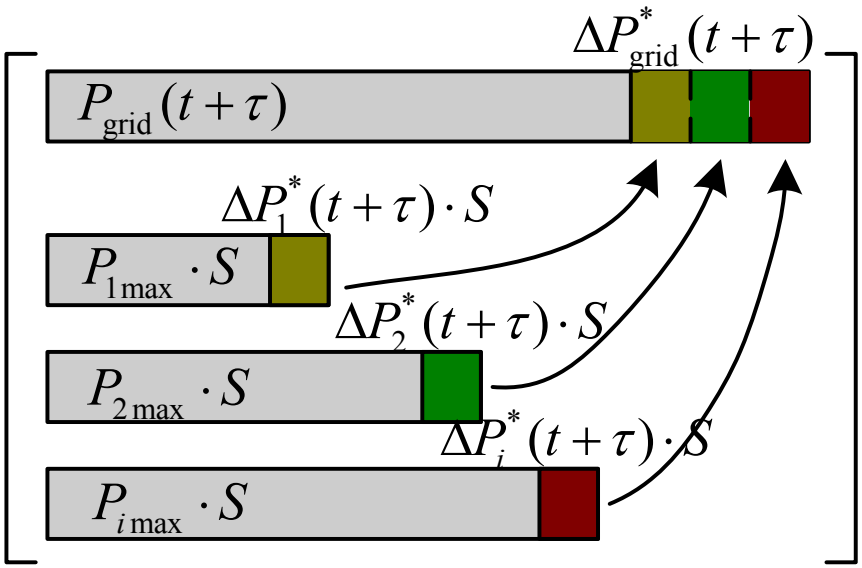
3.1 Energy storage unit in nanogrid

- Damping the high-frequency pulsating power requirement.
  Plug and play, improved droop control for Soc balancing.
- initiative electricity bargain.
  current control/power control
- Passive electricity bargain, follow the control center of nanogrid
  current control/power control

3.Decentralized SOC Balancing Strategy

3.2 Nanogrid control in microgrid

- Balancing the supply and load
- The main adjustable unit is gas turbine
- Centralized control or multi agent control



3.Decentralized SOC Balancing Strategy

3.3 SOC balancing control strategy in nanogrid

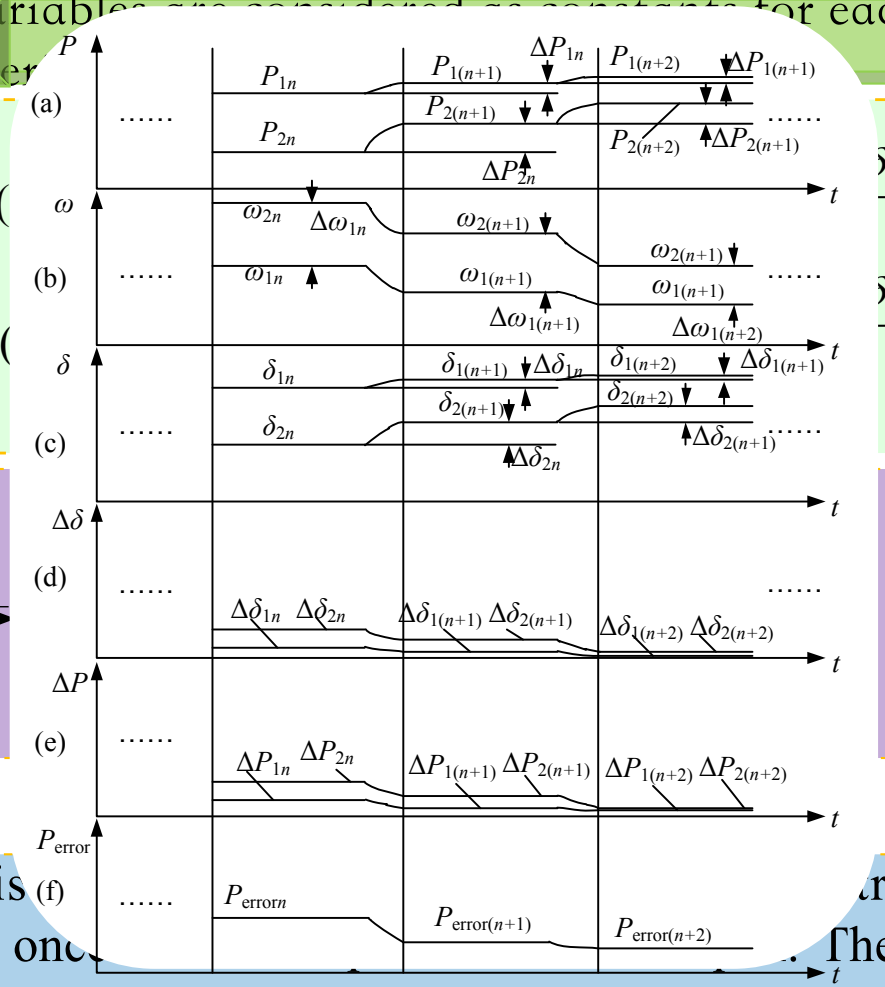
Time Discretization: the variables are considered as constants for each sampling period when the sampling per

Timing diagram

$$\begin{cases} \Delta\delta_{1n} = \delta_{1(n+1)} - \delta_{1n} = \left.\dfrac{d\delta_1}{dt}\right|_n \cdot \Delta T = (\\ \Delta\delta_{2n} = \delta_{2(n+1)} - \delta_{2n} = \left.\dfrac{d\delta_2}{dt}\right|_n \cdot \Delta T = (\end{cases}$$

$$\frac{\delta_{1(n+1)} - \delta_{1n})}{X_1} = \frac{EV\Delta\delta_{1n}}{X_1}$$

$$\frac{\delta_{2(n+1)} - \delta_{2n})}{X_2} = \frac{EV\Delta\delta_{2n}}{X_2}$$



P_n → K_P →

The active power is … transient regulation will occur onc… The power angle is the "medium" connecting active power and frequency.

3.Decentralized SOC Balancing Strategy

3.3 SOC balancing control technology

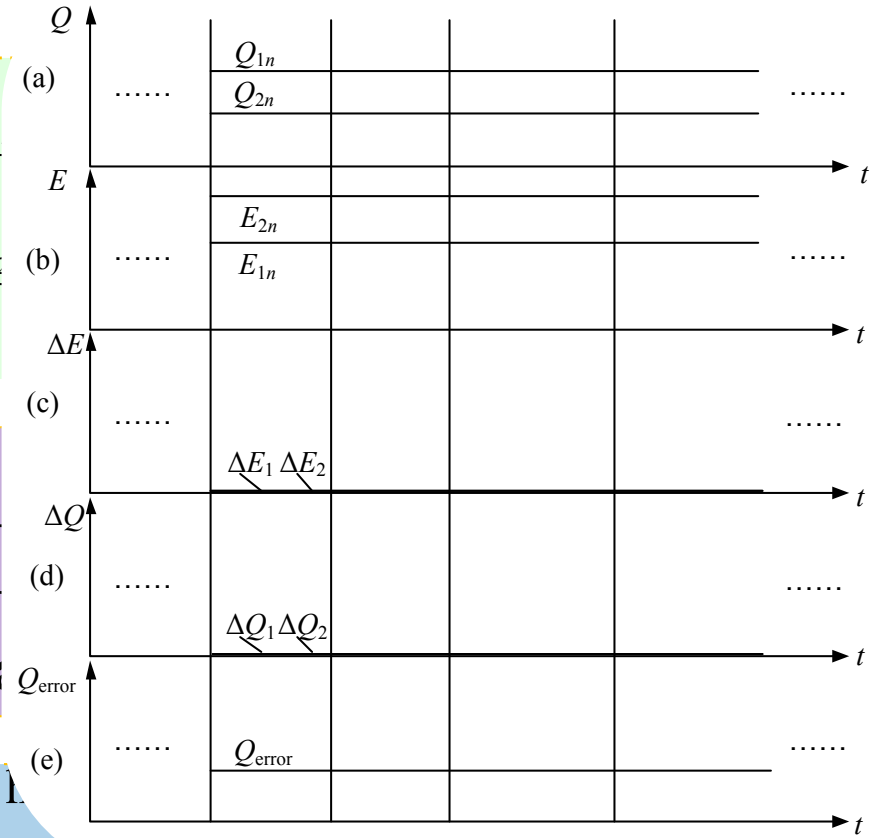
Timing diagram

Time discretization

$$\begin{cases} \Delta Q_{1n} = Q_{1(n+1)} - Q_{1n} = \dfrac{V(E_{1(n+1)} - E_1}{X_1} \\ \Delta Q_{2n} = Q_{2(n+1)} - Q_{2n} = \dfrac{V(E_{2(n+1)} - E_2}{X_2} \end{cases}$$

$(n-1)} - Q_{1n})$

$(n-1)} - Q_{2n})$



Q_n

Block di

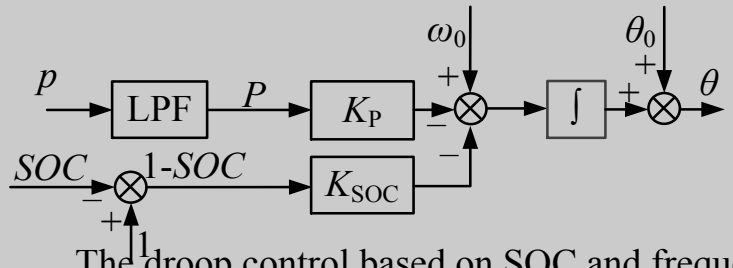
The reactive power l nd
even if the reactive pow state,
it will not cause transient regulation, and there is no medium for
connection voltage and reactive power

3.Decentralized SOC Balancing Strategy

3.3 SOC balancing control technology

The transient regulation process based on droop control

$$\omega = \omega_0 - K_P \cdot P - K_{SOC}(1-SOC)$$



The droop control based on SOC and frequency

- The droop term of K_{SOC}(1-SOC) makes the energy storage unit with larger SOC has higher frequency and higher output active power, and vice versa ;
- The droop term of $K_P P$ realizes the active power sharing, which provides the necessary condition for the SOC balancing;
- The droop term of $K_P P$ is essential 。

3.Decentralized SOC Balancing Strategy

3.3 SOC balancing control technology

Steady state

$$\begin{cases} \omega_1 = \omega_0 - K_{\mathrm{P}} \cdot P_1 - K_{\mathrm{SOC}}(1-\mathrm{SOC}_1) \\ \omega_2 = \omega_0 - K_{\mathrm{P}} \cdot P_2 - K_{\mathrm{SOC}}(1-\mathrm{SOC}_2) \end{cases}$$

$$\begin{aligned} \omega_1 &= \omega_0 - K_P \cdot P_1 - K_{SOC1}(1-SOC_1) \\ &= \omega_2 = \omega_0 - K_P \cdot P_2 - K_{SOC2}(1-SOC_2) \end{aligned}$$

$$\mathrm{SOC}_1 = \frac{K_{\mathrm{SOC2}}\,\mathrm{SOC}_2 + K_{\mathrm{SOC1}} - K_{\mathrm{SOC2}}}{K_{\mathrm{SOC1}}}$$

- SOC is related to droop coefficient;
- SOC is balancing with the same droop coefficient in steady state.

3.Decentralized SOC Balancing Strategy

3.3 SOC balancing control technology

Transient verificati

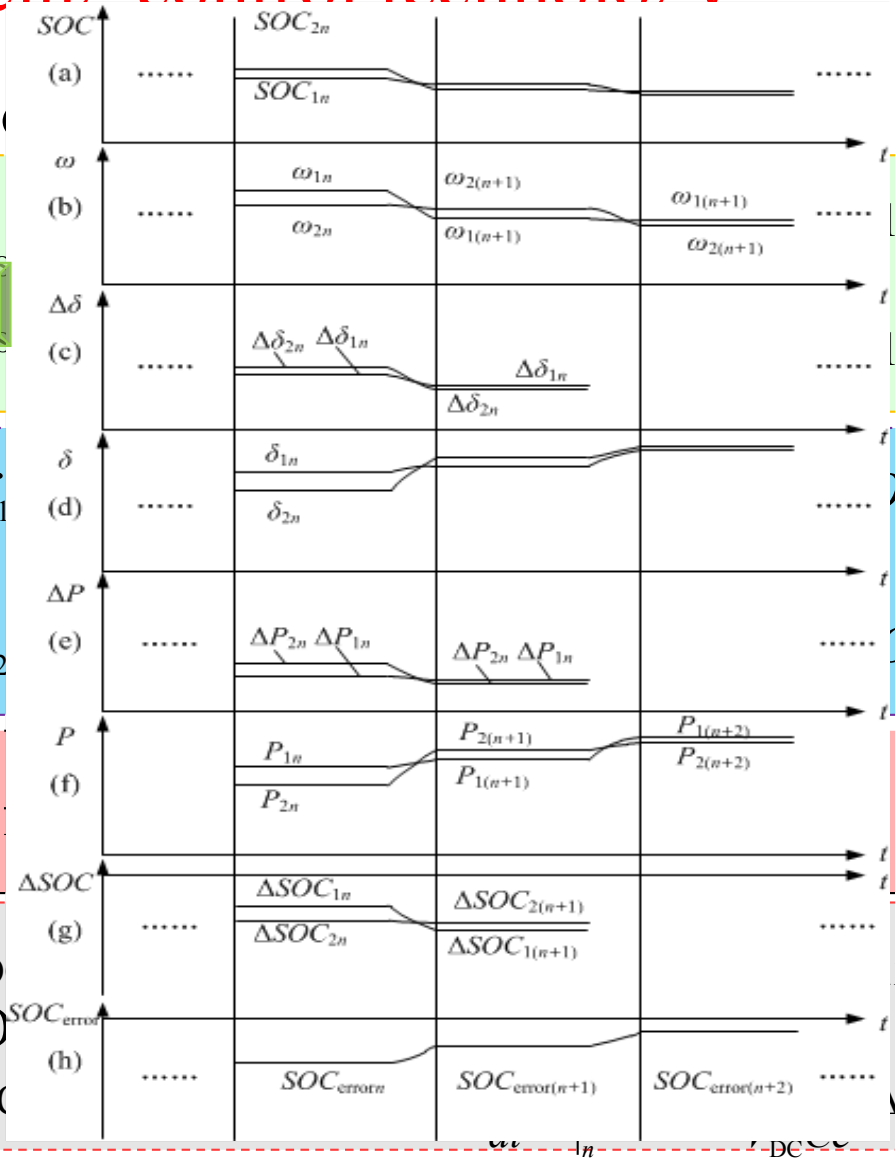
Timing diagram

$$\begin{cases} \omega_{1(n+1)} = \omega_0 - K_s \\ \omega_{2(n+1)} = \omega_0 - K_s \end{cases}$$

$$\begin{cases} \Delta\delta_{1n} = \delta_{1(n+1)} - \delta_1 \\ \Delta\delta_{2n} = \delta_{2(n+1)} - \delta_2 \end{cases}$$

The change rate o

The variation of SO



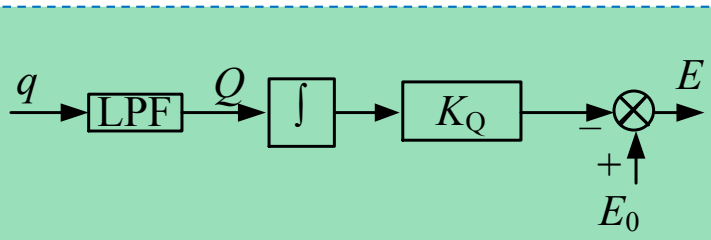
3.Decentralized SOC Balancing Strategy

3.4 Reactive power sharing control technology

$$E = E_0 - K_Q \cdot \int Q dt$$

Introducing the medium of connecting reactive power and voltage" ——— E'

$$E' = \frac{dE}{dt} = -K_Q \cdot Q$$



3.Decentralized SOC Balancing Strategy

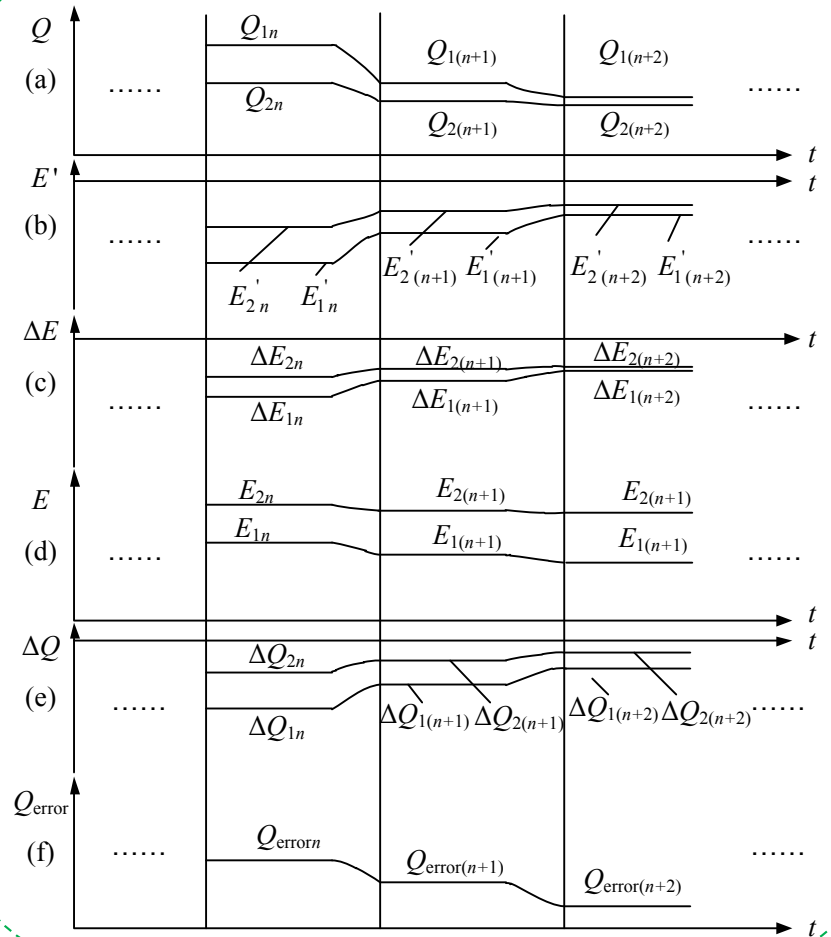
3.4 Reactive power sharing control technology

$$\begin{cases} E_{1(n+1)} = E_0 - K_Q \cdot \int_0^{n\Delta T} Q_1 dt \\ E_{2(n+1)} = E_0 - K_Q \cdot \int_0^{n\Delta T} Q_2 dt \end{cases}$$

$$\begin{cases} E_1'|_n = \left.\dfrac{dE_1}{dt}\right|_n = \dfrac{E_{1(n+1)} - E_{1n}}{\Delta T} = -K_Q \cdot Q_{1n} \\ E_2'|_n = \left.\dfrac{dE_2}{dt}\right|_n = \dfrac{E_{2(n+1)} - E_{2n}}{\Delta T} = -K_Q \cdot Q_{2n} \end{cases}$$

$$\begin{cases} \Delta E_{1n} = E_1'|_n \cdot \Delta T = -K_Q \cdot Q_{1n} \cdot \Delta T \\ \Delta E_{2n} = E_2'|_n \cdot \Delta T = -K_Q \cdot Q_{2n} \cdot \Delta T \end{cases}$$

$$\begin{cases} \Delta Q_{1n} = Q_{1(n+1)} - Q_{1n} = \dfrac{\Delta E_{1n} V}{X_1} \\ \Delta Q_{2n} = Q_{2(n+1)} - Q_{2n} = \dfrac{\Delta E_{2n} V}{X_2} \end{cases}$$



3.Decentralized SOC Balancing Strategy

3.4 Reactive power sharing control technology

Mathematical analysis

Time discretization

$$E_n = E_0 - \frac{Q}{0.7}$$

The microgrid containing N PCS

$$(i = 1, 2, 3, \ldots\ldots, N)$$

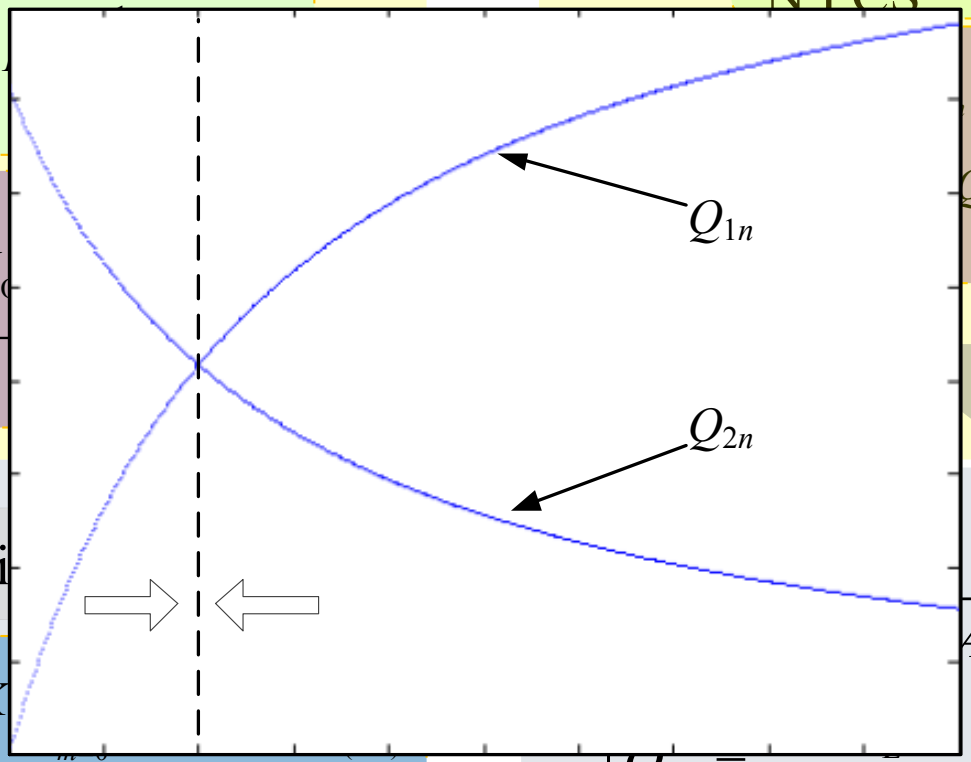
$$Q_m = Q_L$$

$$Q_n = \frac{V(E_0 - K}{0.4}$$

Power ratio

$$\mu_{in} = \frac{Q_{in}}{Q_{(i+1)n}} = \frac{E_0 - K_Q \cdot \sum_{m=0}^{n-1} Q_{(i+1)m} - V}{E_0 - K_Q \cdot \sum_{m=0}^{n} Q_{(i+1)m} - V}$$

$$A = \sum_{k=1}^{N-1} \left(1 \Big/ \sum_{m=1}^{k} \mu_m\right)$$



3.Decentralized SOC Balancing Strategy

3.4 Reactive power sharing control technology

Analysis of droop control characteristic curve

Time discretization

$$\begin{cases} E_{1(n+1)} = E_{1n} - K_Q \cdot Q_{1n} \cdot \Delta T \\ E_{2(n+1)} = E_{2n} - K_Q \cdot Q_{2n} \cdot \Delta T \end{cases}$$

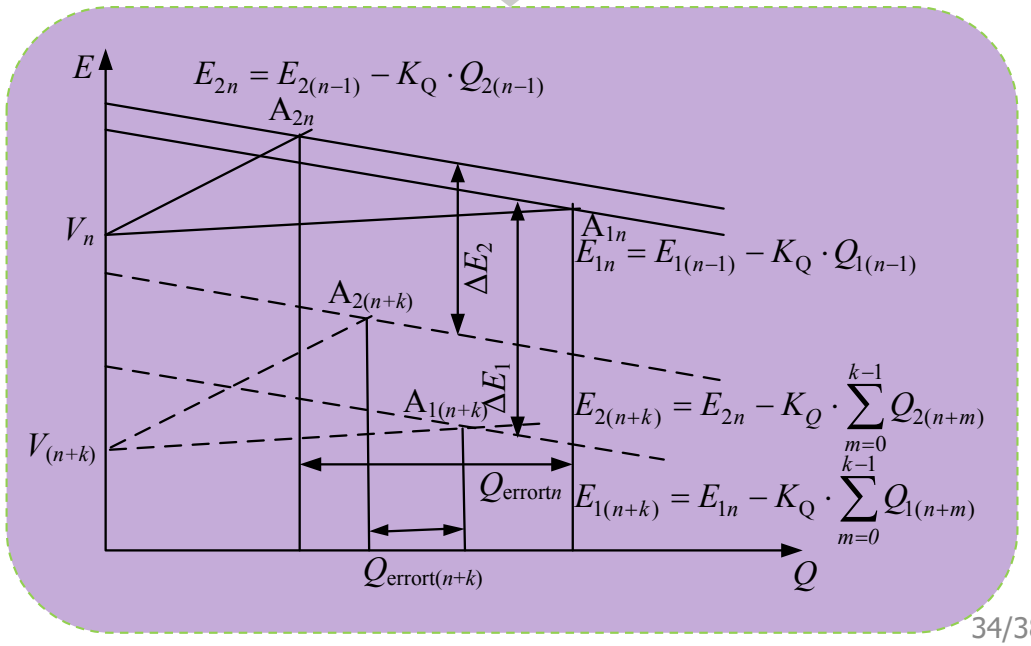
Voltage droop and power transfer point are the operating points,the regulating process of $n \rightarrow n+k$

Voltage droop during $n \rightarrow n+k$ sampling period

$$\begin{cases} E_{1(n+k)} = E_{1n} - K_Q \cdot \sum_{m=0}^{k-1} Q_{1(n+m)} \cdot \Delta T \\ E_{2(n+k)} = E_{2n} - K_Q \cdot \sum_{m=0}^{k-1} Q_{2(n+m)} \cdot \Delta T \end{cases}$$

Power transmission at $n \rightarrow n+k$

$$\begin{cases} E_{1(n+k)} = V_{n+k} + \dfrac{X_1}{V} \cdot Q_{1(n+k)} \\ E_{2(n+k)} = V_{n+k} + \dfrac{X_2}{V} \cdot Q_{2(n+k)} \end{cases}$$

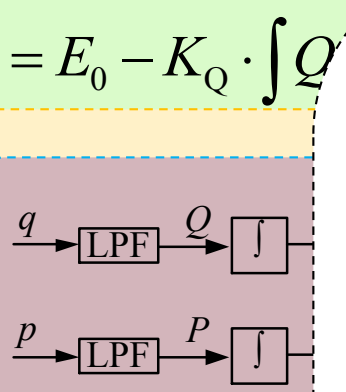


3.Decentralized SOC Balancing Strategy

3.4 Reactive power sharing control technology

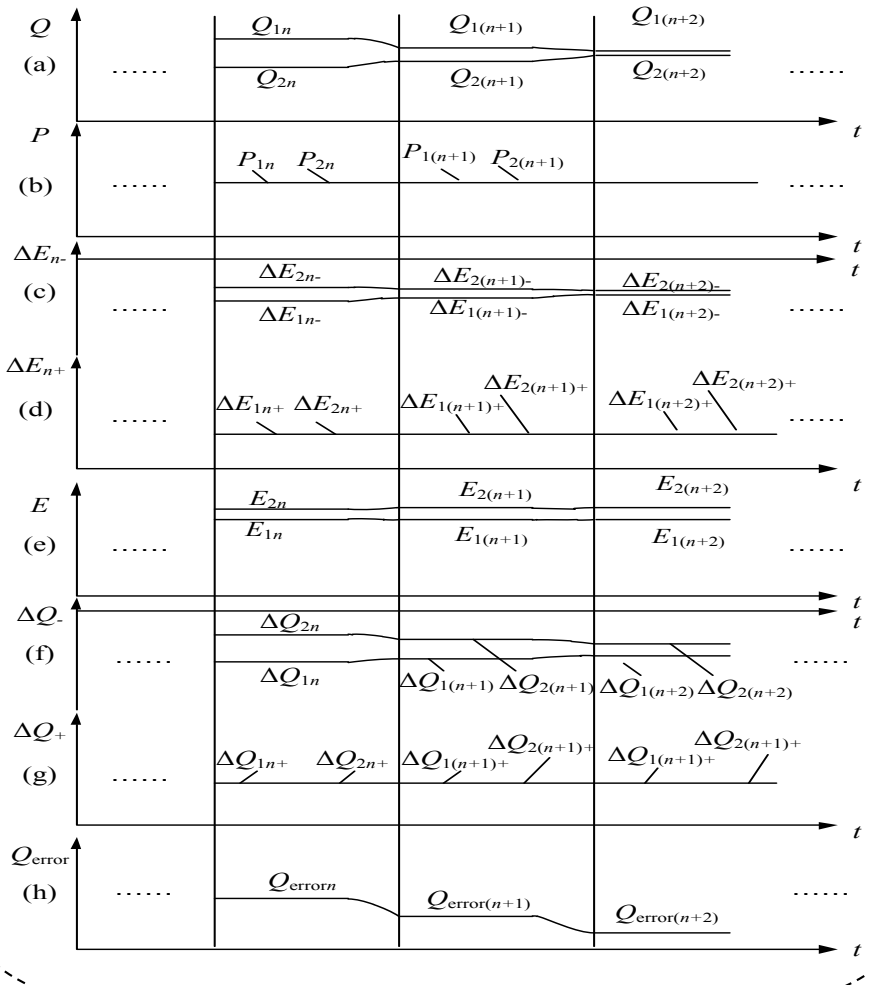
The voltage compensation control and transient verification based on $\int P\mathrm{d}t$-V

$$E = E_0 - K_Q \cdot \int Q$$



Time disc

$$\begin{cases} E_{1(n+1)} = E_0 - K_Q \cdot \sum_{m=1}^{n} Q \\ E_{2(n+1)} = E_0 - K_Q \cdot \sum_{m=1}^{n} Q \end{cases}$$



cycle variation

$$Q_{1n} \cdot \Delta T + K_{PV} \cdot P_{1n} \cdot \Delta T$$

$$Q_{2n} \cdot \Delta T + K_{PV} \cdot P_{2n} \cdot \Delta T$$

cle variation

$$n = \frac{V \cdot \Delta E_{1n+}}{X_1}$$

$$n = \frac{V \cdot \Delta E_{2n+}}{X_2}$$

Contents

4.Conclusion

- The grid connected microgrid with storage uint and gas turbine is the main actor in alternative source generation in future.
- the storage battery would be a household appliances and every home might be a basic unit of a nanogrid.
- Nanogrid acts as a basic trading settlement unit in microgrid. Every home acts as a basic trading settlement unit
- A improved droop control is proposed to realize the decentralized SOC balancing.

Thank you ！

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