Research on Optical Energy Storage System Based on Rule Logic Control

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Abstract. Photovoltaic energy storage system is composed of photovoltaic power generation, energy storage battery, load and power grid, it has researched on different modes of bi-directional DC/AC converter, taking into account a variety of photovoltaic output fluctuations, energy storage battery charging and discharging management, load increasing and decreasing, etc. Aiming at the energy management strategy, using DC bus voltage fluctuation as the basis of energy layer mobilization, the power balance control based on regular control is proposed. Compared with the DC bus voltage level energy management, the power tracking accuracy is further improved and energy loss is reduced. Finally, through MATLAB/Simulink being in off/connected model and the charging/discharging model, the effectiveness of the energy control strategy was verified separately by simulation. The simulation results show that: the proposed control strategy can improve the power tracking accuracy and reduce the energy loss of the system; the proposed strategy guarantees the bidirectional exchange of system energy and maintains the power balance in the network, the DC bus voltage is stable, and the energy storage battery achieves smooth power output and peak load shifting.

1 Introduction

In the field of new energy power generation, such as photovoltaic power generation and wind power generation, there are volatility, intermittency and randomness. These unavoidable factors will cause output power fluctuations and bring non-negligible negative effects on the grid and load. The integrated application of energy and energy storage devices can help improve the local consumption of renewable energy and solve the power fluctuations in the grid caused by intermittent energy output [1-3]. How to solve the time and space mismatch between production capacity and energy use through energy storage, and realize the efficient use of large-scale renewable energy is the focus of the energy Internet research. At the same time, because it contains a variety of energy flow conditions, how to achieve different units Inter-energy management and coordinated control are also a major research focus. In response to this hot spot, a lot of research has been done in related literature [4-6].

Aiming at the problem that photovoltaic power generation is affected by external environmental factors such as light intensity and temperature, the output power fluctuates, and the stability is affected when it is connected to the grid. An energy storage battery is designed as an energy storage device to achieve complementary solar storage systems. The energy of each part is the flow takes the DC bus as the connection point. It is proposed to use the DC bus voltage fluctuation as the basis for energy layer transfer, and the power balance control based on rule logic control as the corresponding energy management control

strategy to realize the load, energy storage battery, photovoltaic power generation and power grid. Energy flow between. The charging and discharging effect of the energy storage battery realizes smooth photovoltaic output power fluctuations, so that the power of photovoltaic power input to the grid remains stable for a certain period of time, realizes the function of peak shaving and valley filling, and reduces the impact of intermittent power output fluctuations on power quality.

2 Optical storage system topology

The composition diagram of the photovoltaic energy storage system is shown in Figure 1. The entire system is output by photovoltaic modules through maximum power tracking (MPPT) to ensure the maximum utilization of photovoltaic energy. The energy storage converter (PCS) is used to realize the two-way exchange of energy with the grid, and the energy storage battery is used to solve the fluctuation of photovoltaic output. The energy required by the load is first met by photovoltaic output, and the shortfall is provided by the grid or energy storage batteries. Energy storage batteries mainly ensure that the energy flow within the grid is in a balanced state. Finally, a complementary system model for optical storage is established to achieve smooth output.

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3.1 System energy management solution

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graph LR
    Upv[Upv] --> CM[Calculation Module]
    UBat[UBat] --> CM
    UDCmax[UDCmax] --> CM
    CM -- VDC --> WSM[Working status selection module]
    WSM --> PTM[Power tracking calculation module]
    PBat[PBat] --> PTM
    Ppv[Ppv] --> PTM
    Pload[Pload] --> PTM
    PTM --> MSM[Mode selection module]
    MSM --> ESC[Energy storage device charging]
    MSM --> ESD[Energy storage device discharging]
  
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3.2 Regular control mode and energy flow state

2

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graph TD
    Input["Pload · Ppv · PBatt  
Upv · UBatt · UDCDC"] --> Logic["Logic rule control module"]
    Logic --> D1{"UDC > UH2 < UDC < UL1"}
    D1 -- Y --> D2{"ΔPPV · ΔPBatt < ΔPload"}
    D1 -- N --> D3{"UH1 < UDC < UH2"}
    D2 -- Y --> D4{"SOC < 85%"}
    D2 -- N --> D4
    D3 -- Y --> D5{"ΔPPV = ΔPBatt + ΔPload"}
    D3 -- N --> D6{"PPV is sufficient"}
    D4 -- Y --> Mode1["Mode 1"]
    D4 -- N --> Mode5["Mode 5  
Energy storage device  
stop working"]
    D5 --> D7{"SOC > 20%"}
    D6 -- Y --> D8{"ΔPPV + |ΔPBatt| = ΔPload"}
    D6 -- N --> D9{"ΔPPV < ΔPBatt + ΔPload"}
    D7 -- Y --> Mode3["Mode 3"]
    D7 -- N --> D10{"SOC < 20%"}
    D8 --> D10
    D9 --> D11{"SOC < 85%"}
    D10 -- Y --> Mode3
    D10 -- N --> Mode4["Mode 4"]
    D11 --> Mode4
    Mode1 --> Mode5
    Mode2 --> Mode5
    Mode3 --> Mode5
    Mode4 --> Mode5
    
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The flowchart illustrates the logic rule control module for the power distribution system. It starts with an input block providing power and voltage parameters: $P_{load} \cdot P_{pv} \cdot P_{Batt}$, U_{pv} , U_{Batt} , and U_{DCDC} . These inputs feed into the 'Logic rule control module'. The module's logic proceeds through several decision diamonds:

- Decision 1:** $U_{DC} > U_{H2} < U_{DC} < U_{L1}$. If 'Y' (Yes), it proceeds to Decision 2. If 'N' (No), it proceeds to Decision 3.
- Decision 2:** $\Delta P_{PV} \cdot \Delta P_{Batt} < \Delta P_{load}$. If 'Y', it proceeds to Decision 4. If 'N', it also proceeds to Decision 4.
- Decision 3:** $U_{H1} < U_{DC} < U_{H2}$. If 'Y', it proceeds to Decision 5. If 'N', it proceeds to Decision 6.
- Decision 4:** $SOC < 85\%$. If 'Y', it leads to Mode 1. If 'N', it leads to Mode 5 (Energy storage device stop working).
- Decision 5:** $\Delta P_{PV} = \Delta P_{Batt} + \Delta P_{load}$. It leads to Decision 7.
- Decision 6:** P_{PV} is sufficient. If 'Y', it leads to Decision 8. If 'N', it leads to Decision 9.
- Decision 7:** $SOC > 20\%$. If 'Y', it leads to Mode 3. If 'N', it leads to Decision 10.
- Decision 8:** $\Delta P_{PV} + |\Delta P_{Batt}| = \Delta P_{load}$. It leads to Decision 10.
- Decision 9:** $\Delta P_{PV} < \Delta P_{Batt} + \Delta P_{load}$. It leads to Decision 11.
- Decision 10:** $SOC < 20\%$. If 'Y', it leads to Mode 3. If 'N', it leads to Mode 4.
- Decision 11:** $SOC < 85\%$. It leads to Mode 4.

Finally, Modes 1, 2, 3, 4, and 5 all lead to Mode 5, which is labeled 'Energy storage device stop working'.

4 Simulation and experiment

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Using different energy management strategies to track the actual load demand and photovoltaic output, the results are shown in Figure 6 and Figure 7. The results show that the energy management strategy based on rule logic control reduces the tracking loss of photovoltaic output and load forecasting, and improves the power tracking accuracy.

Fig4. Load demand tracking

Fig5. Save energy during peak hours(%)

4.2 Mode switching simulation

4.2.1 Grid-connected state mode switching simulation

The initial operating light intensity of the system is 600W/m^2 . The lack of power on the DC side causes a large drop in the DC side bus voltage, and the energy storage battery power supply energy is insufficient. The system working mode is 5, the PCS works in the rectifying state, and the AC side delivers energy to charge the battery. The light intensity rises to 1000W/m^2 by 0.8s, the photovoltaic output is increased from the original 196kW to 498.9kW , the system working mode is switched from 5 to 1, the photovoltaic output is sufficient and the energy storage battery still has remaining power transmitted to the grid after working at the upper limit of charge. In the whole process, the DC bus voltage is basically stable at about 715V .

Fig6. DC voltage bus

Fig7. Rectifier and inverter mode switching

4.2.2 Simulation analysis of off-grid state mode switching

When operating off-grid, photovoltaic output and energy storage battery output jointly maintain power balance while ensuring that photovoltaics are used to the maximum.

When the photovoltaic output is 498.9kW in 0-0.8s, when the operation reaches 0.8s, due to the change of the external environment, the light intensity suddenly drops from 1000W/m^2 to 600W/m^2 and the output power drops to 196kW . Figure 8 shows the power required by the load, which is 350kW for 0-1.5s and 450kW for 1.5s-3s.

Fig8. Energy storage battery power

5 Conclusion

This article aims to stabilize the DC bus voltage and accurately track the actual demand of photovoltaic output and load by the energy storage battery to achieve peak shaving and valley filling. The power balance control based on rule logic control is designed to achieve 5 modes of optical storage system operation, and then the two-way DC/ Control strategies for DC converters and energy storage converters.

The simulation results show that the energy management strategy based on rule-based logic control proposed in this paper corresponds the working mode of the energy storage converter and the charging and discharging state of the energy storage battery to the specific working conditions, and solves the problem that may be caused by the fluctuation of photovoltaic output when the external environment changes. System power imbalance problem, and stabilize the DC bus voltage, use energy storage battery to achieve smooth output power, and achieve the goal of peak clipping and valley filling. At the same time, it achieves accurate tracking of photovoltaic output and load demand, and improves power tracking accuracy, which proves the effectiveness

of this strategy in reducing system energy loss and improving energy utilization.

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