



Real-time Optimization Scheduling and Reliability Evaluation of Hydrogen Energy in the New Power System

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SUMMARY: *Under the background of high proportion of renewable energy grid connection in the new power system, hydrogen energy, due to its advantages of cross-period energy storage and multi-form conversion, has become an important support for improving the flexibility and reliability of the system. This paper focuses on the problem of real-time optimization scheduling of the power system involving hydrogen energy, builds a hydrogen-electric coupling operation model, sets up the collaborative mechanism of electrolyzers, hydrogen storage devices and fuel cells, and on this basis, introduces the model predictive control strategy to form a scheduling framework for the rolling time domain. Moreover, reliability assessment is carried out by combining indicators such as load shedding rate, energy supply sufficiency and equipment availability rate. The simulation results show that the established model reduces the wind and solar energy rejection rate by 18.7%, lowers the operation cost by 12.4%, increases the power supply reliability rate of the system to 99.36%, and controls the average power deviation in load fluctuation scenarios within 3.8%. The research indicates that the synergy of hydrogen energy and MPC can effectively enhance the real-time regulation ability and overall safe operation level of the new power system.*

KEYWORDS: *New power system; Model predictive control; Real-time optimal dispatch; Reliability assessment*

1 Introduction

Under the background of the continuous progress of the "double carbon" goal and large-scale grid connection of new energy, the operation pattern of the new power system is gradually shifting from the traditional source with load to the strong fluctuation structure of both source and load dominated by a high proportion of wind power and photovoltaic. Affected by multiple factors such as meteorological conditions, random load disturbances and changes in equipment operating status, the difficulty of real-time system balance has increased significantly. The conventional regulation mode of relying on thermal power unit hill climbing and rotating reserve has been difficult to fully adapt to the rapid response needs of the new power system. Hydrogen energy has the characteristics of electron-hydrogen-electricity multi-form conversion, inter-time storage and flexible call, which can establish a new coupling channel between new energy consumption, power peak-filling, reserve support and emergency supply protection, thus becoming one of the key technical paths to improve the resilience and reliability of the new power system.

Compared with traditional energy storage, the hydrogen energy system not only involves

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the cooperation of multiple devices such as electrolyzer, hydrogen storage device and fuel cell, but also is affected by conversion efficiency, start-stop constraints, hydrogen storage boundary and multi-time scale coupling. The scheduling problem of hydrogen energy system shows stronger dynamic, discrete and nonlinear characteristics. This means that it is difficult to accurately describe the changing power gap and equipment state evolution process in actual operation only by relying on static optimization or single-period economic dispatch. With the development of intelligent perception, edge computing, online prediction and rolling optimization algorithms, embedding computer modeling methods into the scheduling decision chain has become an important direction to improve the real-time control ability of the system. In particular, the online optimization framework represented by Model Predictive Control (MPC) can use short-term prediction information to make rolling corrections for output deviation, load change and hydrogen storage state in the future time domain, so as to enhance the adaptability of the scheduling scheme to uncertainties.

Based on this, the research on the real-time optimal scheduling and reliability evaluation of hydrogen energy in the new power system has not only clear engineering value, but also strong theoretical significance. This paper takes the hydrogen-electric coupled operation scenario as the research object, constructs a collaborative model including electrolyzed hydrogen production, hydrogen storage regulation and fuel cell power generation, analyzes the support mechanism of hydrogen energy on system power balance, operation economy and power supply security under the real-time optimization framework, and further incorporates the load reduction rate, energy supply adequacy and equipment availability into the unified evaluation system. To reveal the linkage relationship between scheduling effect and system reliability.

2 Literature review

Concerning the problem of hydrogen energy participating in the operation optimization of new power system, the existing research has generally experienced an evolution process from single scenario optimization to multi-link collaboration, from static dispatching to rolling control, and from economic objective to reliability constraint expansion. Early studies mainly focus on the wind-hydrogen energy system or the electric-hydrogen integrated energy system, focusing on day-ahead scheduling, capacity coordination and multiple uncertainty handling. Related methods mainly include data-driven optimization, stochastic scheduling and multi-energy flow coupling modeling. This kind of research has better revealed the basic role of electrolytic hydrogen production, hydrogen storage and fuel cells in new energy consumption and peak filling, laying a model foundation for subsequent real-time scheduling research, but the discussion on short-term disturbance response and online correction mechanism is relatively limited [1-4]. On this basis, some scholars have begun to incorporate multiple hydrogen energy utilization methods, hydrogen mixing scenarios and demand response mechanisms into a unified optimization framework, so that hydrogen energy is no longer regarded as a simple long-term energy storage medium, but gradually evolved into an important regulation node connecting the energy supply side, load side and conversion side. The research at this stage enhanced the integrity of system modeling and improved the degree of detail of resource utilization analysis, but most of the results were still focused on plan-level optimization, and the description of real-time state update and rapid reconstruction ability was still insufficient [5, 6].

With the increasing fluctuation of new energy output, multi-time scale rolling optimization has gradually become the research focus. Starting from different objects such as integrated energy system, electric-hydrogen coupled system and transport-energy cooperative

system, related researches introduce the ideas of rolling horizon optimization, hierarchical scheduling and online update, trying to maintain the continuity and stability of system operation under the condition of prediction errors. Meanwhile, computer intelligence methods such as deep reinforcement learning have also been applied to complex energy management problems, showing certain advantages in state perception, policy iteration and nonlinear decision-making [7-10]. However, these methods often rely on high quality data samples and a long training process, which still face interpretability and stability constraints in engineering real-time applications. From the perspective of research focus, in recent years, more attention has been paid to the safety, toughness and reliability of hydrogen energy systems. Some studies focus on the stochastic operation and market participation mechanism of hydrogen-containing integrated energy systems, and analyze the scheduling risk under uncertain environments. Another part of the research has incorporated safety constraints, tenacity oriented decision-making and equipment availability evaluation into the model, promoting hydrogen energy scheduling research from "economic feasibility" to "safe and credible" [11-17]. In addition, related studies on hydrogen refueling stations, local energy systems, off-grid integrated energy stations and smart grid resilience also illustrate the potential value of hydrogen storage in improving energy supply sustainability and resisting disturbance shocks from different aspects [18-22]. As shown in Table 1, the existing research has formed a clear hierarchy in the method path and application focus, but there are still obvious research gaps in the integration of "real-time scheduling-online correction-reliability evaluation".

Table 1: Main progress and shortcomings of research on hydrogen energy participation in new power system dispatch

Research Category	Representative References	Main Methods	Research Focus	Main Limitations
Day-Ahead Optimization and Uncertainty Scheduling	[1]-[4]	Data-driven optimization, stochastic optimization, multi-energy flow modeling	Renewable energy accommodation, cost control, coordinated operation	Insufficient real-time correction capability
Multi-Coupling and Demand Response Optimization	[5]-[6]	Electricity-hydrogen coupling modeling, coordinated demand response	Multi-scenario hydrogen utilization, resource allocation optimization	Inadequate characterization of dynamic disturbance response
Multi-Time-Scale Rolling Scheduling and Intelligent Optimization	[7]-[10]	Rolling optimization, hierarchical scheduling, reinforcement learning	Online decision-making, state updating, dynamic control	Engineering deployment and interpretability remain limited
Stochastic Operation and Risk-Constrained Analysis	[11]-[17]	Stochastic optimization, risk aversion, security-constrained scheduling	Uncertainty management, resilience improvement	Insufficient integration with reliability index systems
Local System Resilience and Comprehensive Evaluation	[18]-[22]	Off-grid optimization, local system modeling, review analysis	Supply continuity, equipment availability, system resilience	Overall coordination for new power systems still needs to be strengthened

In general, the existing results have provided a rich accumulation of methods for modeling, rolling control and risk analysis of hydrogen energy dispatching, but there is still room for further deepening the research for new power systems. First, real-time optimal dispatching and reliability evaluation are often treated separately, and a closely linked unified analysis framework has not yet been formed. Secondly, although MPC or intelligent algorithms are introduced in some studies, the discussion on how to map the online solution results to reliability indicators such as load reduction rate, energy supply adequacy and equipment availability is still not sufficient. Third, the computational synergy relationship between multiple devices, multiple state variables and the rolling optimization process in the hydrogen-electric coupled system still needs to be further refined.

3 Basic support and operation requirements for real-time scheduling of hydrogen energy in the new power system

3.1 The supporting effect of hydrogen coupling generation side and energy storage side on system stability

Under the condition of high proportion of wind power and photovoltaic grid-connected, the random fluctuation of generation side output and the time-varying disturbance of load side demand add up to each other, which makes the new power system more prone to short-term power imbalance, reserve margin contraction and local adjustment lag. After the intervention of hydrogen energy, a bi-directional adjustable coupling link is formed between the generation side and the storage side. When the output of new energy is higher than the real-time absorption capacity, the electrolytic cell can convert the excess electric energy into hydrogen energy and transfer it to the hydrogen storage unit. When the system has a power gap or the climbing pressure increases, the fuel cell then converts the hydrogen energy back to electric energy to realize the flexible compensation across time scales. Such a closed loop of "electricity-hydrogen-storing-electricity" not only changes the operation mode of new energy that can only passively follow the load, but also provides a computable and callable buffer variable for the real-time scheduling algorithm, as shown in Figure 1.

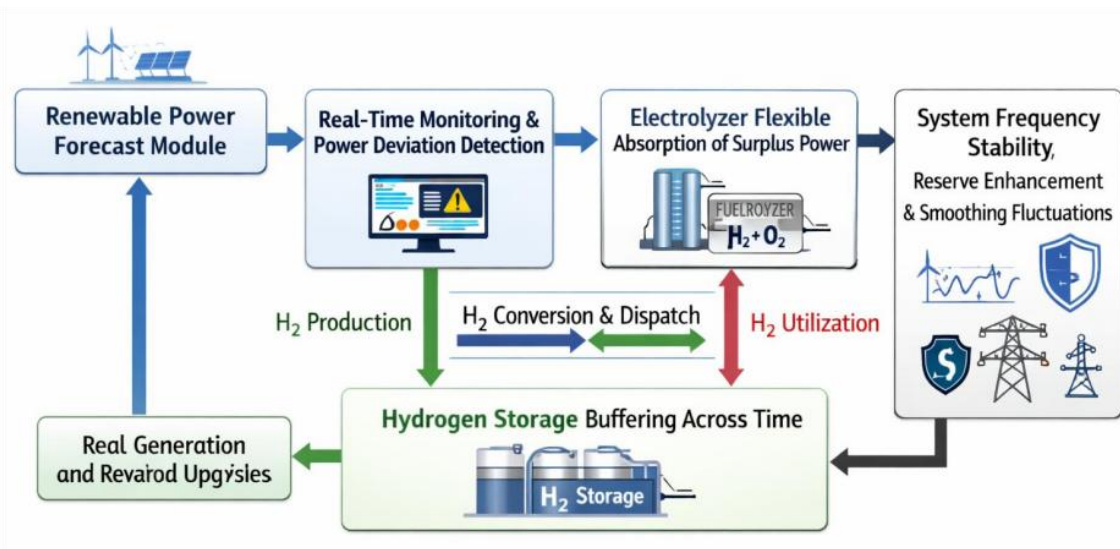


Figure 1: Schematic diagram of the action path of hydrogen-energy coupling support system stabilization on generation side-energy storage side

To characterize the instantaneous equilibrium state of the system after hydrogen energy coupling, the net power deviation can be expressed as:

$$\Delta P_t = P_t^{\text{ren}} + P_t^{\text{fc}} + P_t^{\text{g}} - P_t^{\text{el}} - P_t^{\text{L}} \quad (1)$$

where, P_t^{ren} is the new energy output, P_t^{fc} is the fuel cell output, P_t^{g} is the conventional unit output, P_t^{el} is the electrolytic cell power consumption, and P_t^{L} is the load demand. When ΔP_t is close to zero, it indicates that the real-time equilibrium state of the system is good. Compared with traditional battery energy storage, hydrogen energy storage not only assumes the task of fast power compensation, but also provides energy transfer capability in the process of long-term fluctuations, so as to reduce the regulation pressure caused by frequent start and stop of conventional units. The state evolution of the hydrogen storage unit can be further written as:

$$H_{t+1} = H_t + \eta_{\text{el}} P_t^{\text{el}} \Delta t - \frac{P_t^{\text{fc}} \Delta t}{\eta_{\text{fc}}} \quad (2)$$

Here, H_t represents the amount of hydrogen storage at time t , η_{el} and η_{fc} are the efficiency of hydrogen production by electrolysis and fuel cell power generation, respectively, and Δt is the scheduling step. The state equation enables the hydrogen storage system to be included in the state space of the computer online scheduler, which is continuously updated in the process of rolling optimization or predictive control, and provides a basis for subsequent power allocation and safety constraint judgment. From the perspective of stability, the value of hydrogen energy is not only reflected in filling the power gap, but also reflected in the calming effect on net load climbing. To describe this effect, the net load fluctuation intensity after hydrogen energy participation can be defined as:

$$R_t = |(P_t^{\text{L}} - P_t^{\text{ren}}) - (P_t^{\text{fc}} - P_t^{\text{el}})| \quad (3)$$

The smaller R_t is, the more obvious is the hedging effect of hydrogen energy on load fluctuations. With the help of real-time monitoring, short-term prediction and online solution module, the dispatching system can dynamically determine the allocation level of absorbed power of the electrolyse cell and the support power of the fuel cell according to the changes of R_t and H_t , so as to absorb fluctuations on the generation side and slow release shocks on the energy storage side, and jointly improve the frequency stability, reserve availability and continuous power supply ability of the system.

3.2 The mechanism of improving resource utilization under the cooperative operation of electrolytic hydrogen production and fuel cells

In the new power system, the time mismatch of new energy output and the continuous fluctuation of load demand do not occur synchronously. If only relying on the energy storage conversion in a single direction, it will often cause the phenomenon of insufficient surplus power absorption and insufficient compensation ability during power shortage. The cooperative operation of electrolytic hydrogen production and fuel cells establishes a cyclic switchable resource transfer channel between the period of surplus power generation and the period of power shortage, so that electric energy, hydrogen energy and regulation ability can be reorganized in a unified dispatching platform. The key is not to simply add an energy

storage link, but to transform "when to produce hydrogen, when to generate electricity, and how much power to switch" into a computable sequential decision problem through state identification, short-term prediction and online solution. As shown in Table 2, this synergistic mechanism acts on three levels simultaneously: new energy consumption, equipment utilization, and system energy supply matching.

Table 2: Resource utilization improvement mechanism for the cooperative operation of electrolytic hydrogen production and fuel cells

Coordination Stage	Main Operating Mode	Resource Utilization Improvement Path	Computational Support Content
Renewable Energy Surplus Absorption	The electrolyzer increases power consumption and produces hydrogen	Reduce wind and solar curtailment and improve renewable energy utilization	Short-term renewable energy forecasting, surplus power identification, online power allocation
Cross-Period Energy Transfer	The hydrogen storage unit preserves energy in an intermediate form	Shift instantaneous surplus electricity to subsequent power-deficit periods	State estimation, hydrogen storage boundary monitoring, rolling updating
Reverse Support During Power Deficit Periods	The fuel cell generates electricity on demand to compensate for the deficit	Reduce the peak-regulation pressure on conventional generating units and improve supply-demand matching	Net load forecasting, marginal power scheduling, real-time solving
Coordinated Equipment Switching	Hydrogen production mode and power generation mode switch mutually exclusively	Reduce ineffective round-trip conversion losses and improve overall efficiency	Mode discrimination variables, mutual exclusion constraints, scheduling logic control
System-Level Resource Optimization	Electric power and hydrogen power are jointly incorporated into the scheduling platform	Achieve coordination of energy flow, equipment flow, and control flow	Data acquisition, state-space modeling, optimization algorithm invocation

To describe the real-time absorption effect of new energy resources, the utilization rate of renewable energy in time period t can be defined as:

$$\eta_t^{re} = 1 - \frac{P_t^{cur}}{P_t^{ava}} \quad (4)$$

Among them, P_t^{cur} is the power of abandoned wind and light, and P_t^{ava} is the output of available new energy. The electrolyzer is put into operation preferentially when new energy is surplus, which can directly compress the scale of P_t^{cur} and thus improve η_t^{re} . This means that the hydrogen energy system not only assumes the energy storage function, but also plays the role of "adjustable load" in real-time scheduling.

To avoid invalid hedging of hydrogen production by electrolysis and fuel cells at the same

time period, mutually exclusive operation constraints can be set:

$$P_t^{el} \leq u_t P_t^{el,max}, P_t^{fc} \leq (1 - u_t) P_t^{fc,max} \quad (5)$$

where, u_t is a pattern discriminant variable; When $u_t=1$, the system is in the hydrogen production absorption state, and when $u_t=0$, the system turns to the fuel cell support state. The constraint can be embedded into a rolling optimization procedure to ensure that the device runs in the same direction as the system requirements and reduce unnecessary energy round-trip losses. At the scheduling level, it is also necessary to measure the improvement effect of collaborative operation on the matching degree of net load, and the hydrogen energy adjustment error can be written as:

$$E_t = |\hat{P}_t^{net} - (P_t^{fc} - P_t^{el})| \quad (6)$$

Here, \hat{P}_t^{net} represents the net load deviation output by the prediction model. The smaller E_t is, the more suitable the power switching between the electrolyzer and the fuel cell is for the real-time needs of the system. Relying on the computer online prediction and solution module, the dispatch center can continuously modify the equipment output according to the dynamic changes of E_t , so that more new energy is converted into hydrogen reserves in the period of surplus, and then released in the form of fuel cells in the period of power shortage, so as to improve the utilization rate of new energy, improve the operation efficiency of equipment and the continuity of energy supply.

3.3 Low carbon value and flexible adjustment ability of hydrogen energy integrated into new energy system

In the new power system, the reason why hydrogen energy has independent dispatch value is not only because it can assume the function of energy storage, but also because it can transform the fluctuating new energy power into clean energy that can be invoked across time periods, thus acting on emission reduction constraints and regulation constraints at the same time. The output of wind power and PV often shows obvious unbalanced characteristics of timing. When the real-time output exceeds the upper limit of local load absorption and delivery capacity, some clean electricity will be forced to reduce if there is no effective conversion link. After the electrolysis hydrogen production device is connected, this part of the marginal surplus electricity can be converted into hydrogen reserves. In the subsequent period of net load rise, reserve tension or local fluctuation enhancement, the reverse energy release through the fuel cell is formed, and a continuous chain of "low carbon absorption - intertemporal transfer - flexible release" is formed. Such operation mechanism makes hydrogen energy no longer an auxiliary facility outside the new energy system, but gradually transformed into a flexible resource that can be identified, predicted and called by the dispatch center. From the perspective of low carbon effect, the system emission reduction after hydrogen energy participation can be expressed as:

$$C^{red} = \sum_{t=1}^T \rho^g (P_t^{g,base} - P_t^{g,opt}) \quad (7)$$

where, ρ^g is the unit carbon emission coefficient of conventional thermal power units, $P_t^{g,base}$ and $P_t^{g,opt}$ respectively represent the thermal power output under the conditions of no hydrogen energy regulation and hydrogen energy regulation. This equation shows that the

contribution of hydrogen energy to emission reduction is not generated in isolation, but is reflected by replacing part of the high-carbon peak shaving power. From the perspective of flexible regulation, the regulation coverage coefficient of time period t can be further defined as:

$$\Psi_t = \frac{P_t^{\text{fc,ava}} + P_t^{\text{el,cut}}}{|P_t^{\text{net}}| + \varepsilon} \quad (8)$$

where, $P_t^{\text{fc,ava}}$ are the output of fuel cells that can be adjusted up, $P_t^{\text{el,cut}}$ are the load of electrolyzer that can be adjusted down, P_t^{net} is the net regulation demand of the system, and ε is the minimal amount introduced to avoid the denominator being zero. If Ψ_t is closer to or greater than 1, it means that the hydrogen energy system is more capable of covering real-time fluctuations. This index is especially suitable to be embedded in the online optimization program to determine whether the current hydrogen storage state and equipment capacity are sufficient to support the regulation task in the next rolling period. In order to characterize the smoothing effect of hydrogen energy on the fluctuation of new energy, the residual fluctuation quantity after coupling can also be defined as:

$$V_t = |(P_t^{\text{w}} + P_t^{\text{pv}} + P_t^{\text{fc}} - P_t^{\text{el}}) - (P_{t-1}^{\text{w}} + P_{t-1}^{\text{pv}} + P_{t-1}^{\text{fc}} - P_{t-1}^{\text{el}})| \quad (9)$$

Among them, P_t^{w} and P_t^{pv} represent wind power and PV output, respectively. The smaller V_t indicates that the system is more fully buffered against the new energy output jump after hydrogen energy participation. Relying on the prediction model, the state estimation module and the rolling solver, the dispatch center can continuously update the change trend of C^{red} , Ψ_t and V_t , and dynamically modify the hydrogen production power, hydrogen storage level and fuel cell output distribution accordingly, as shown in Figure 2. It can be seen that the significance of integrating hydrogen into the new energy system is not only to expand the scale of clean energy consumption, but also to provide computational support resources with both low carbon attributes and real-time regulation capabilities for the new power system.

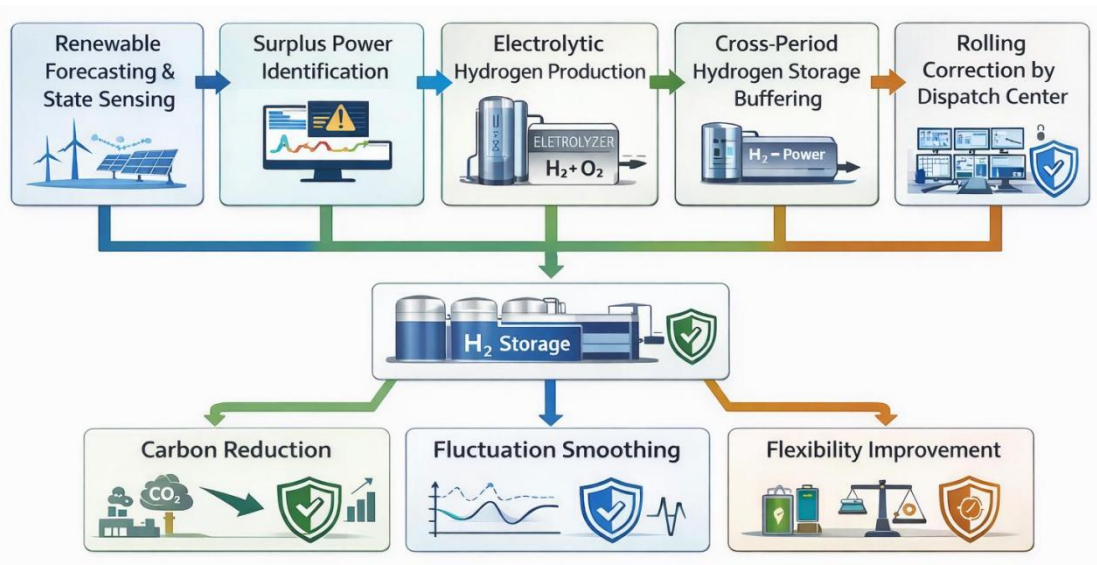


Figure 2: Mechanism diagram of low carbon value and flexible adjustment ability of hydrogen energy integrated into new energy system

3.4 Resource coupling constraint analysis in real-time optimal scheduling

In the hydrogen energy system with electrolytic hydrogen production as the core link, the real-time optimal scheduling is not a single power variable, but a multi-dimensional operation process coupled with power input, hydrogen production water, hydrogen storage state and load response. If we only focus on the electric power balance and ignore the dependence of the electrolysis link on the continuous supply of water resources, water treatment capacity and water supply fluctuation, the scheduling results may be true in the power side, but they are often difficult to be stably executed in the actual operation. Especially in the scenario of rapid fluctuation of new energy output and frequent switching of hydrogen production load, water resource supply capacity is no longer an ancillary condition, but an important constraint affecting the efficiency of real-time hydrogen energy deployment. Therefore, the hydrogen energy scheduling for the new power system needs to incorporate the "power availability-water supply availability-hydrogen production executability" into the unified timing framework, and realize the collaborative judgment through online calculation.

From the perspective of operation mechanism, there is a direct correspondence between the water consumption per unit time of electrolytic hydrogen production and the electrolytic load, which can be expressed as:

$$Q_t^{\text{use}} = \mu P_t^{\text{el}} \Delta t \quad (10)$$

Here, Q_t^{use} is the water consumption for hydrogen production at time period t , μ is the water consumption coefficient corresponding to unit electric power, P_t^{el} is the power of the electrolyzer, and Δt is the scheduling step. This equation shows that the higher the output of the electrolyzer, the higher the requirement for the real-time supply of water resources. If the response of the water supply side lags behind, it will weaken the absorption capacity of surplus new energy. Considering the dynamics of the tank or the water purification unit, the water storage can be further written as:

$$S_{t+1}^w = S_t^w + Q_t^{\text{in}} - Q_t^{\text{use}} - Q_t^{\text{loss}} \quad (11)$$

where, S_t^w is the available water storage at time t , Q_t^{use} is the replenishment water, and Q_t^{loss} is the treatment and transportation loss. The state equation can be embedded in a real-time scheduler, so that the dispatching center can update the power state and the water supply state synchronously during the rolling solution, so as to avoid the scheduled hydrogen production power not being realized due to the insufficient water side margin. Based on this, the hydroelectric cooperative executable power can be defined as:

$$P_t^{\text{we}} = \min \left(P_t^{\text{sur}}, \frac{Q_t^{\text{ava}}}{\mu \Delta t} \right) \quad (12)$$

Here, P_t^{sur} is the surplus renewable electricity in time period t , and Q_t^{ava} is the water available for immediate dial-up. This formula shows that the actual implementation level of hydrogen production by electrolysis is determined by the surplus power and the available water, and the shortage of either side will compress the hydrogen energy adjustment space. As shown in Table 3, the collaborative demand of hydropower in real-time optimal scheduling is not limited to the resource supply itself, but involves many levels such as state perception, online prediction, constraint coupling and control response. With the help of sensor acquisition, digital modeling and rolling optimization algorithm, the system can realize the synchronous adjustment of water supply link and electrolytic load under the condition of new

energy fluctuations, so as to ensure that hydrogen energy scheduling is both feasible in calculation and practical in engineering.

Table 3: Main requirements of hydropower cooperative operation in real-time optimal scheduling

Demand Dimension	Specific Content	Impact on Real-Time Scheduling	Computational Support Method
Power-Side Matching Demand	Track changes in surplus wind and solar power and dynamically allocate electrolyzer power	Determines the scale of renewable energy accommodation and the timing of hydrogen production startup	Short-term forecasting, rolling optimization, power allocation algorithms
Water-Side Assurance Demand	Ensure the continuous, stable, and adjustable water supply required for power-to-hydrogen conversion	Affects whether the planned hydrogen production power can be implemented as scheduled	Water volume monitoring, state estimation, inventory updating
State Coupling Demand	Simultaneously consider electric power, water storage, and hydrogen storage states	Prevents operational mismatch caused by one-sided optimization	Multi-state variable modeling, online coordinated solving
Response Speed Demand	Adapt to frequent switching under rapid renewable energy fluctuations	Determines the tracking accuracy and stability of real-time scheduling	Real-time data acquisition, edge computing, rapid iteration
Safety Constraint Demand	Satisfy water treatment capacity, equipment startup/shutdown, and operating boundary requirements	Ensures that the scheduling scheme is executable and free from overload	Constraint embedding, threshold judgment, anomaly warning

4 Construction of real-time optimal scheduling and reliability evaluation model of hydrogen energy in new power system

4.1 Modeling of hydrogen-electric coupling system structure and key state variables

In order to accurately describe the operation process of hydrogen energy participating in real-time dispatching of new power system, this paper defines the research object as a hydrogen-electric coupling system composed of new energy output unit, conventional regulating unit, electrolytically produced hydrogen device, hydrogen storage unit, fuel cell, load center and online dispatching module. Figure 3 shows the overall structure of the system. Among them, wind power and photovoltaic provide clean power with fluctuation, the electrolyze cell absorbs power and converts it into hydrogen in the period of surplus power, the hydrogen storage unit assumes the energy buffer across periods, and the fuel cell reverses the energy release in the period of power shortage, so as to enhance the real-time balance ability and power supply continuity of the system. Relying on sensing acquisition, short-term

prediction and online solving procedures, the scheduling center continuously updates the state of each link, thus forming a closed-loop control structure of "prediction-decision-execution-feedback".

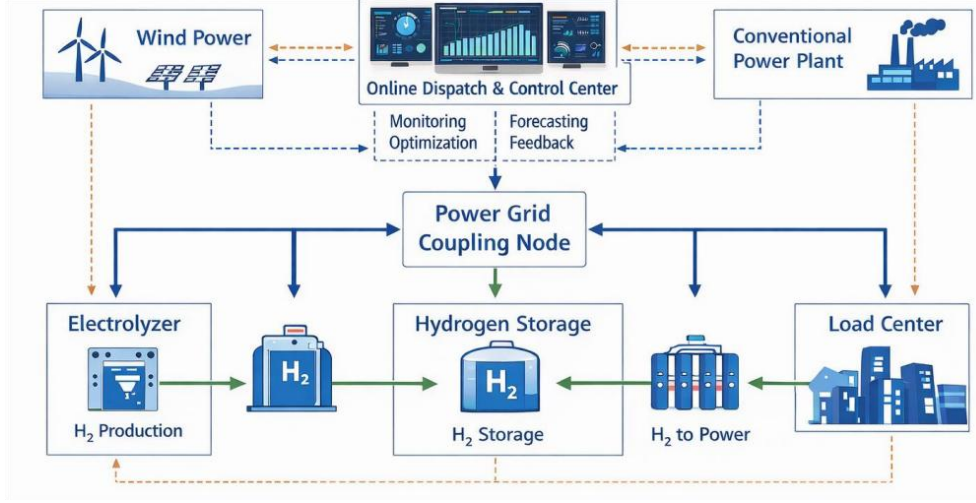


Figure 3: Schematic diagram of the hydrogen-electric coupling system structure

On the discrete scheduling period t , the system power coupling relationship can be expressed as

$$P_t^{\text{bal}} = P_t^w + P_t^{\text{PV}} + P_t^g + P_t^{\text{fc}} - P_t^{\text{el}} - P_t^L - P_t^{\text{loss}} \quad (13)$$

where, P_t^w and P_t^{PV} represent the output of wind power and PV respectively, P_t^g represents the output of conventional units, P_t^{fc} is the power generated by fuel cells, P_t^{el} is the power consumed by electrolytic cells, P_t^L is the load demand, and P_t^{loss} is the network loss. P_t^{bal} reflects the net balance state of the system at that time slot and is the direct basis for subsequent scheduling decisions. The hydrogen storage state is the core variable in the hydrogen-electric coupling model, and its dynamic change can be written as

$$M_{t+1} = M_t + \kappa_{\text{el}} P_t^{\text{el}} \Delta t - \frac{P_t^{\text{fc}} \Delta t}{\kappa_{\text{fc}}} \quad (14)$$

Here, M_t represents the amount of hydrogen stored at time t , κ_{el} is the conversion coefficient of hydrogen production by electrolysis, κ_{fc} is the conversion coefficient of fuel cell energy release, and Δt is the scheduling step. The equation integrates the conversion process of hydrogen production and power generation into the same state update framework, so that the hydrogen storage can be continuously tracked as a state quantity in the rolling optimization. Considering the unified representation of multi-source states by real-time scheduling, the system state vector can be further defined as

$$s_t = [P_t^w, P_t^{\text{PV}}, P_t^L, M_t, u_t^{\text{el}}, u_t^{\text{fc}}, R_t^{\text{up}}]^T \quad (15)$$

Among them, u_t^{el} and u_t^{fc} represent the operating status of the electrolyzer and fuel cell, respectively, and R_t^{up} represents the system up-reserve capacity. The state vector contains not only continuous power variables, but also equipment operating state and safety margin variables, which is convenient for state estimation, constraint discrimination and online

optimization solution in computer programs.

4.2 Real-time optimization scheduling objective function and multi-run constraint design

After the structural modeling of the hydrogen-electric coupling system is completed, the key to real-time optimal scheduling is to integrate economic operation, power tracking and supply reliability into the same solution goal. To this end, this paper defines the comprehensive operation cost in the scheduling period as the weighted sum of the conventional unit output cost, the electrolytically hydrogen production conversion cost, the fuel cell call cost, the load loss penalty, and the state deviation penalty. The correspondence between the objective function and the constraints is shown in Figure 4. Among them, the forecasting module outputs the scenery output and load demand, and the online solver updates the control quantity according to the equipment status and constraint boundaries in each rolling period, so as to form a closed-loop process of "prediction-optimization-executing-correction". Compared with the static scheduling that simply pursues the lowest cost, this goal design emphasizes the executability and reliability of scheduling results in engineering scenarios. The integrated objective function can be expressed as

$$\min J = \sum_{t=1}^T \left[\sum_{i \in \Omega_g} c_i P_{i,t} + c^{el} P_t^{el} + c^{fc} P_t^{fc} + \alpha L_t^{ls} + \beta (\Delta f_t)^2 \right] \quad (16)$$

where Ω_g is the set of conventional units, c_i, c^{el} and c^{fc} represent the unit operating cost of units, electroreduction cells and fuel cells respectively, L_t^{ls} is the loss of supply load, Δf_t is the system frequency or equivalent power deviation, α and β are penalty coefficients. This equation shows that the model not only suppresses high-cost output, but also imposes significant penalties on load shedding and dynamic deviations to avoid the degradation of system security caused by local optima. To ensure that the real-time scheduling results meet the supply-demand balance, the total node power constraint is set as

$$\sum_{i \in \Omega_g} P_{i,t} + P_t^w + P_t^{pv} + P_t^{fc} + L_t^{ls} = D_t + P_t^{el} + R_t^{sp} \quad (17)$$

Here, D_t is the total system load and R_t^{sp} is the system up-reserve or safety margin demand. This constraint makes the power consumption of fuel cell generation and electrolytic hydrogen production be handled synchronously in a unified power balance scheme. Considering the equipment response speed and the continuity of online scheduling, it is also necessary to add the climbing constraint

$$-\Gamma_k^\downarrow \leq P_{k,t} - P_{k,t-1} \leq \Gamma_k^\uparrow, k \in \Omega_g \cup \{el, fc\} \quad (18)$$

where, Γ_k^\uparrow and Γ_k^\downarrow represent the upper and lower climbing limits of the equipment, respectively. This constraint can prevent the optimizer from giving too drastic power jumps in adjacent periods and improve the practical executability of scheduling instructions. In addition, to reflect the reliability requirements, equipment availability and reserve adequacy should be introduced into the operating boundary:

$$P_t^{fc} + R_t^{up} \leq \bar{P}^{fc} A_t^{fc}, P_t^{el} \leq \bar{P}^{el} A_t^{el} \quad (19)$$

Among them, \bar{P}^{fc} and \bar{P}^{el} are the rated capacity, and A_t^{fc} and A_t^{el} are the available state coefficients of the equipment. Thus, the system can synchronously determine whether the device has the ability to participate in the adjustment during the calculation process. In general, the joint design of the objective function and multiple operation constraints makes the hydrogen real-time scheduling model not only reflect the economic orientation, but also give consideration to the dynamic stability and power supply security, which provides a direct solution basis for the subsequent rolling optimization and reliability evaluation.

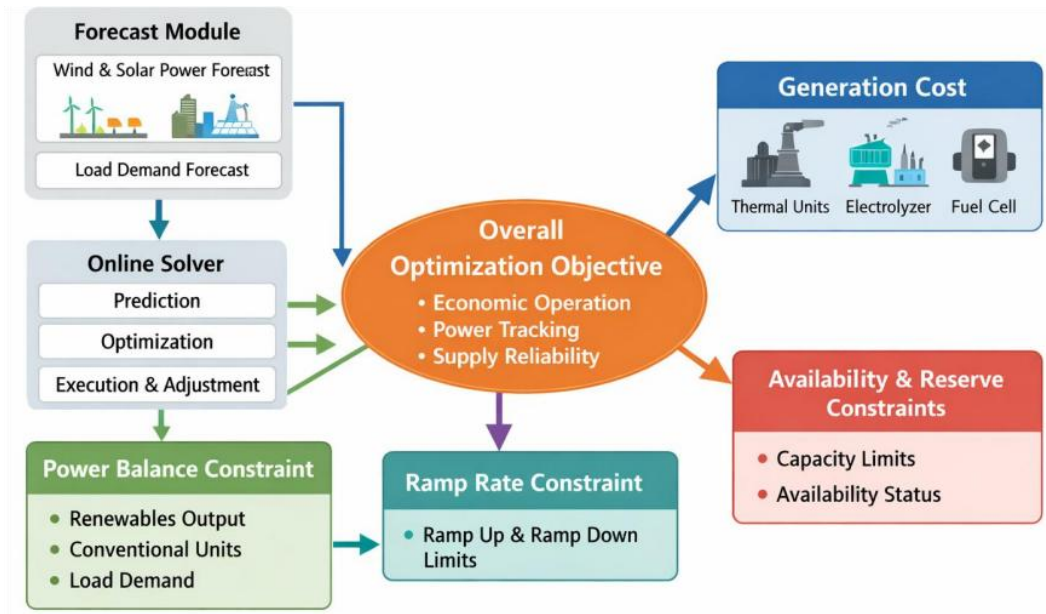


Figure 4: Relationship between objective function and multi-run constraints of real-time optimization scheduling

4.3 Rolling optimal scheduling strategy based on MPC and online solving process

In the new power system, the output of wind power, photovoltaic power and load demand show continuous fluctuation characteristics. If the static scheduling method of fixed time period is still used in the hydrogen-electric coupling system, it is often difficult to correct the operation deviation caused by the prediction deviation and the change of equipment status in time. Therefore, this paper introduces Model Predictive Control (MPC) to construct a rolling optimization scheduling strategy, which uses the latest observation data, short-term prediction results and equipment state information at each sampling time to repeatedly execute the online closed-loop process of "state update - rolling solution - control implementation - feedback correction". The key of the proposed method is not to obtain the full time-domain optimal scheme at once, but to continuously modify the future control sequence within a limited prediction window, so as to improve the adaptability of hydrogen energy scheduling to random disturbances and model errors. The key parameters and online functional division in rolling optimization are shown in Table 4.

Table 4: Key parameters and roles of MPC rolling optimization scheduling

Parameter or Module	Meaning	Main Function	Impact on Real-Time Scheduling
N_p	Prediction horizon length	Determines the foreseeable range of future states and disturbances	Affects global performance and computational burden
Control Horizon	Number of control steps actually involved in optimization	Determines the adjustable depth of control actions	Affects response speed and stability
State Estimation Module	Updates hydrogen storage level, load, and equipment states	Ensures consistency between model inputs and field conditions	Affects solution accuracy
Short-Term Forecasting Module	Outputs forecasts of wind/solar generation and load demand	Provides forward-looking information for rolling optimization	Affects optimization effectiveness
Online Solver	Computes the current optimal control sequence	Generates control actions for the electrolyzer and fuel cell	Affects real-time performance and convergence
Feedback Correction Mechanism	Replaces predicted states with measured states	Suppresses error accumulation	Improves robustness and engineering applicability

At time k , the rolling optimization objective of MPC can be written as

$$\min_{U_k} J_k = \sum_{i=0}^{N_p-1} \left[\lambda_1 (P_{k+i}^{\text{mis}})^2 + \lambda_2 (\Delta u_{k+i})^2 + \lambda_3 C_{k+i}^{\text{op}} \right] + \lambda_4 \Phi(x_{k+N_p}) \quad (20)$$

where N_p is the length of the prediction time domain, U_k is the future control sequence, P_{k+i}^{mis} represents the power mismatch in the future time period, Δu_{k+i} represents the control increment, C_{k+i}^{op} is the operating cost, $\Phi(x_{k+N_p})$ is the terminal state penalty term, and λ_1 to λ_4 are the weight coefficients. The objective function simultaneously constrains the deviation of supply and demand balance, controls the drastic fluctuation of action and operation cost, so that the electrolyzer, hydrogen storage unit and fuel cell can respond coordinately in the rolling time domain. The state update of the system after online prediction can be expressed as

$$\hat{x}_{k+i+1|k} = f(\hat{x}_{k+i|k}, u_{k+i|k}, \hat{d}_{k+i|k}), i = 0, 1, \dots, N_p - 1 \quad (21)$$

where, $\hat{x}_{k+i|k}$ is the predicted value of the state at time k for the future $k+i$ period, $u_{k+i|k}$ is the corresponding control quantity, and $\hat{d}_{k+i|k}$ is the predicted disturbance term. Through this recurrence relationship, the scheduler can remap the hydrogen storage, equipment availability, renewable energy output and load level into a unified state space before each solution, which ensures that the solution results are consistent with the real-time operation scenario. The MPC only implements the first control action at the current instant, and its rolling execution rule can be written as

$$u_k = u_{k|k}^*, x_{k+1} = x_{k+1}^{mea}, k \leftarrow k + 1 \quad (22)$$

Here, $u_{k|k}^*$ is the first optimal control quantity in the current optimization sequence, and x_{k+1}^{mea} is the measured state at the next time. This mechanism enables the system to be re-optimized based on the latest measurement results at each sampling period without being continuously amplified by previous prediction errors. In order to improve the efficiency of online solution, this paper adopts an integrated program framework of "short-term prediction model + rolling optimization solver + state feedback correction" at the implementation level, and combines the previous solution as the warm start initial value to shorten the solution time. At the same time, by setting the length of the prediction window, the length of the control window and the frequency of the state update in a coordinated manner, the balance between the accuracy of the solution and the real-time performance can be achieved.

4.4 System reliability evaluation method and collaborative analysis mechanism driven by scheduling results

After the rolling optimization scheduling is completed, the system operation state is not terminated by the generation of control instructions, and the scheduling output needs to be further transformed into measurable reliability results to test whether the power supply continuity, equipment support ability and risk exposure level are substantially improved after the participation of hydrogen energy. Based on this, this paper constructs a reliability evaluation method composed of scheduling result reading, state index mapping, risk identification-collaborative judgment. The evaluation process and collaboration are shown in Figure 5.

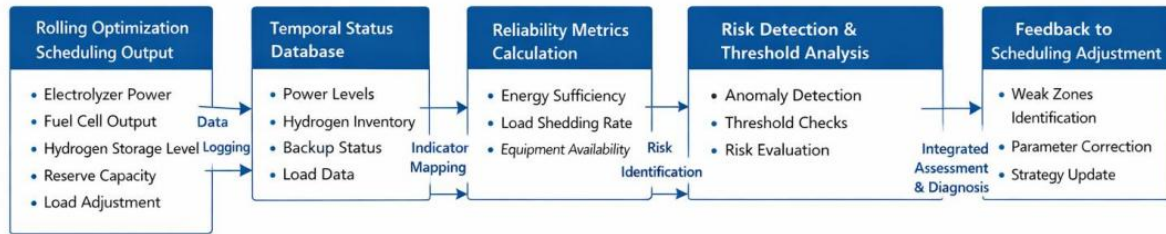


Figure 5: Mechanism diagram of system reliability evaluation and collaborative analysis driven by scheduling results

Among them, the electrolyzer power, fuel cell output, hydrogen storage allowance, reserve level and load correction output of the online scheduling module are uniformly written into the timing state database. The evaluation module tracks the operating safety of the system in each period through index calculation, threshold discrimination and correlation analysis, so as to form a closed loop of reliability analysis directly driven by the scheduling results. To measure the energy supply adequacy of the system in the scheduling period, the energy supply adequacy index is defined as

$$\Theta = \frac{\sum_{t=1}^T (D_t - L_t^{cut})}{\sum_{t=1}^T D_t} \quad (23)$$

Here, D_t is the load demand at time period t and L_t^{cut} is the cut load at the corresponding time period. The closer Θ is to 1, the better the load demand is satisfied by the scheduling

scheme. This index comes directly from the dispatch output, so it can truly reflect the actual guarantee level of the system after hydrogen energy adjustment. Considering the risk of load loss, the load shedding rate can be further defined as

$$\Lambda = \frac{\sum_{t=1}^T L_t^{\text{cut}}}{\sum_{t=1}^T D_t} \quad (24)$$

Λ and Θ complement each other, one characterizes the supply attainment and the other characterizes the loss of supply exposure. For a high proportion of new energy scenarios, if hydrogen storage and fuel cells cooperate effectively, Λ should decrease significantly with scheduling optimization, which is also the key basis to judge whether hydrogen energy really improves system reliability. The support capability at the device level is described by the comprehensive availability rate:

$$\Gamma = \frac{1}{T} \sum_{t=1}^T \frac{\sum_{m \in \Omega_{\text{eq}}} a_{m,t}}{|\Omega_{\text{eq}}|} \quad (25)$$

Here, Ω_{eq} is the set of critical devices, and $a_{m,t}$ represents the available state of device m at time period t . The higher Γ is, the larger proportion of the electrolyzer, hydrogen storage unit, fuel cell and related support equipment remain callable during the scheduling period. When Θ , Λ and Γ are jointly analyzed, the coupling relationship among "whether the energy supply is sufficient, whether the risk is convergent, and whether the equipment is supported" can be identified.

In the calculation implementation, this paper adopts the method of time series data playback and index linkage analysis, inputs the optimized scheduling results into the evaluation program hourly, and combines the threshold alarm rule to identify the high-risk period. When the hydrogen storage allowance is too low, the backup shortage and the load reduction rise synchronously in a certain period of time, the system is judged as the reliability weak interval, and it is reversed marked to the scheduling module for subsequent parameter correction and control strategy update.

5 Results and discussion

5.1 Experimental scenario Settings and key evaluation indicators

In order to verify the real-time scheduling effect and reliability improvement ability of the model in the new power system, this paper constructed a hydrogen-electric coupling simulation scenario including wind power, photovoltaic, conventional units, electrolytic cells, hydrogen storage units and fuel cells. The experimental platform was deployed in Ubuntu 22.04 environment, and Python 3.11 was used to complete data processing and rolling scheduler development. The online optimization module called Gurobi solver, and the scheduling strategy was advanced according to the time resolution of 15 minutes to simulate the running process for 24 hours continuously. In order to reflect the real-time control characteristics, the model reads the latest output prediction, load prediction and equipment state in each rolling period, and updates the control sequence according to the MPC mechanism. In the scene setting, the scenery output curve includes two typical working conditions of high fluctuation and stable, and the superposition of conventional load fluctuation and short-term disturbance is set at the load side to investigate the adaptability of

the hydrogen energy system to different operating pressures. The experimental scenarios and key evaluation indicators are shown in Table 5.

Table 5: Experimental scenario Settings and key evaluation indicators

Item	Setting Content	Function
Simulation Object	Wind power, photovoltaic, conventional generating units, electrolyzer, hydrogen storage unit, fuel cell, load center	Construct the hydrogen-electric coupled operation scenario
Simulation Platform	Ubuntu 22.04, Python 3.11, Gurobi	Support data processing and online optimization solving
Scheduling Method	MPC-based rolling optimization scheduling	Realize the closed-loop control of prediction–solution–feedback
Time Scale	15 min/step, continuous simulation for 24 h	Characterize the real-time scheduling process
Typical Operating Conditions	High-fluctuation wind–solar scenario, stable wind–solar scenario, load disturbance scenario	Verify model adaptability and robustness
Wind and Solar Curtailment Rate	Curtailed renewable energy / available renewable energy	Measure renewable energy accommodation capability
Total Operating Cost	Sum of power generation, hydrogen production, energy release, and penalty costs	Measure scheduling economy
Power Supply Reliability	Ratio of actual supplied load to total load	Measure continuous power supply capability
Load Shedding Rate	Ratio of unsupplied load to total load	Identify system supply security risk
Average Power Deviation	Average deviation between actual balanced power and target value	Evaluate real-time tracking accuracy

The evaluation system not only focuses on economy, but also emphasizes the supporting effect of scheduling results on the safe operation of the system. Among them, the abandoned wind and light rate is used to measure the level of new energy consumption, the comprehensive operation cost is used to reflect the dispatching economy, the reliability rate of power supply is used to describe the continuous power supply ability of the system, the load reduction rate is used to identify the guaranteed supply risk under extreme periods, and the average power deviation is used to evaluate the tracking accuracy of rolling optimization for real-time fluctuations. Through the collaborative analysis of the above indicators, the comprehensive performance of the system in terms of flexible regulation, energy transfer and reliable power supply after hydrogen energy participation can be more completely judged, and it also provides a unified benchmark for subsequent comparison of results under different operating conditions.

5.2 Analysis of real-time optimal scheduling results under different working conditions

After completing the construction of the experimental scene, this paper further selects three representative operating conditions for comparative analysis: condition A is the scene of high proportion of scenery fluctuation, condition B is the scene of evening peak load disturbance,

and condition C is the relatively stable conventional operation scene. The comparison object is the conventional rolling scheduling method without hydrogen energy rolling correction mechanism. As shown in Figure 6, the proposed MPC-based real-time optimal scheduling method for hydrogen energy shows better new energy absorption ability under the three types of operating conditions. In condition A, the wind and light abandonment rate decreases from 14.8% to 11.9%. In condition B, it decreased from 12.6% to 10.1%; In condition C, it decreased from 10.7% to 8.7%. According to the average level, the power abandonment rate of new energy decreased by about 18.7%, indicating that the absorption effect of the electrolytic cell on the surplus power and the inter-period transfer effect of the hydrogen storage unit can effectively buffer the timing mismatch of the output of new energy. Correspondingly, the comprehensive operating costs under the three working conditions decreased by 11.6%, 12.4% and 13.1% respectively, indicating that the participation of hydrogen energy not only improves the level of consumption, but also reduces the additional costs caused by frequent peak shading of conventional units.

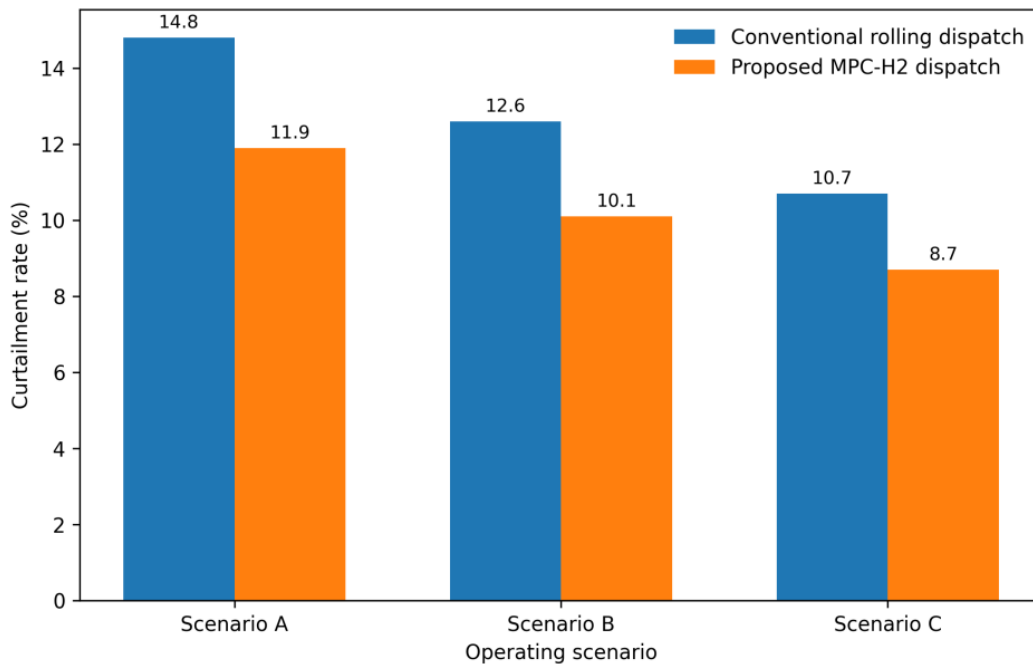


Figure 6: Comparison of wind and light abandonment rates for different operating conditions under real-time optimized scheduling

As shown in Figure 7, the proposed method also outperforms the comparison methods in terms of reliability and real-time tracking performance. Under the conventional scheduling, the reliability rate of power supply for conditions A, B and C is 98.72%, 98.95% and 99.08%, respectively. After using the proposed method, the corresponding indexes increased to 99.21%, 99.36% and 99.31%. Among them, the improvement of condition B is the most obvious, indicating that fuel cells and hydrogen storage resources can provide more targeted power support when the rapid load climbing and new energy fluctuations are superimposed. At the same time, the average power deviation is reduced from 5.7%, 4.9% and 4.3% to 4.1%, 3.8% and 3.6%, respectively, and is controlled within 3.8% in the load disturbance scenario. This shows that the rolling optimization strategy can timely correct the control sequence according to the latest prediction information, and avoid the accumulation and amplification of scheduling deviation in consecutive periods.

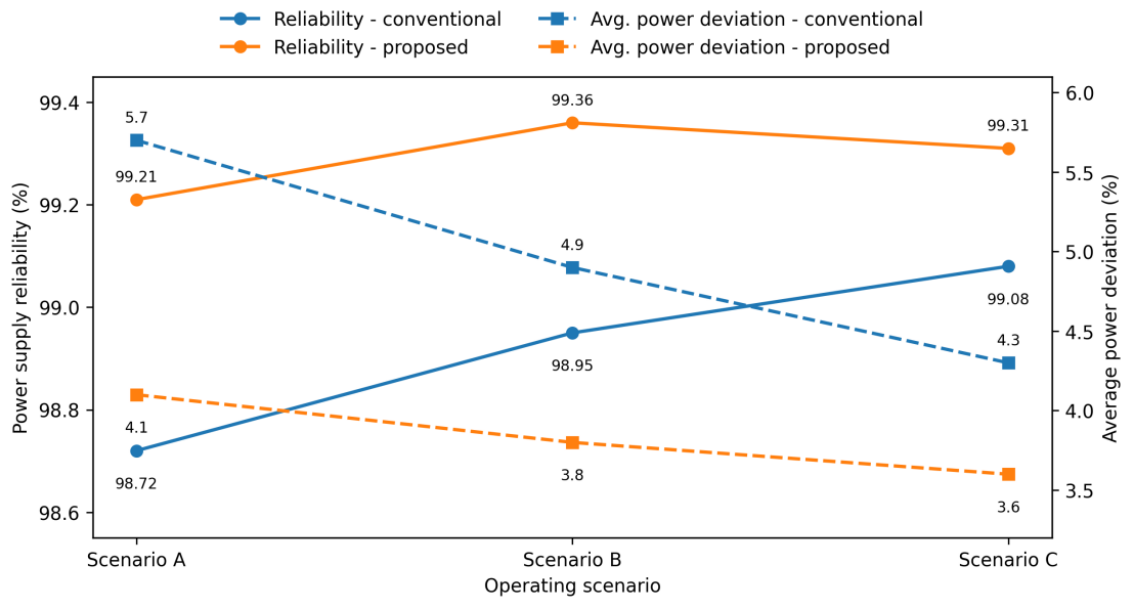


Figure 7: Comparison of power supply reliability rate and average power deviation under different operating conditions

On the whole, the hydrogen energy system shows good real-time adjustment ability under different working conditions, but its effect strength is closely related to the operating pressure. In the high fluctuation condition, the advantages are mainly reflected in the enhanced absorption of new energy. Under the load disturbance condition, the advantages are more manifested in the improvement of power supply reliability rate and power deviation compression. It can be seen that hydrogen energy is not simply an auxiliary unit to supplement electricity, but a key regulatory resource in the new power system with the functions of absorption support, dynamic balance and reliability enhancement.

5.3 Discuss the effects of hydrogen storage configuration parameters and MPC control parameters on the results

Based on the above results, this paper further investigates the sensitivity of the hydrogen storage configuration parameters and MPC control parameters to the scheduling performance. To ensure the consistency of the comparison, this section keeps the wind power output sequence, load curve, and rated capacities of electrolyzer and fuel cell unchanged, and only adjusts the hydrogen storage capacity and MPC prediction step size. As shown in Figure 8, when the hydrogen storage capacity is increased from 200 kg to 400 kg, the comprehensive operating cost of the system decreases significantly. Taking the prediction step size of 8 as an example, the cost is reduced from 416,000 yuan to 381,000 yuan, a decrease of 8.4%. This shows that in the medium capacity range, the hydrogen storage unit can more effectively complete the inter-period transfer of surplus new energy, reduce the call of wind and light abandonment and high-price peak shaving. After the capacity continues to increase to 500 kg and 600 kg, the cost only decreases from 378,000 yuan to 377,000 yuan, and the marginal revenue shrinks significantly, indicating that although the excessive hydrogen storage allocation can improve the buffer surplus, its additional adjustment value has become saturated under the established scenery fluctuation level.

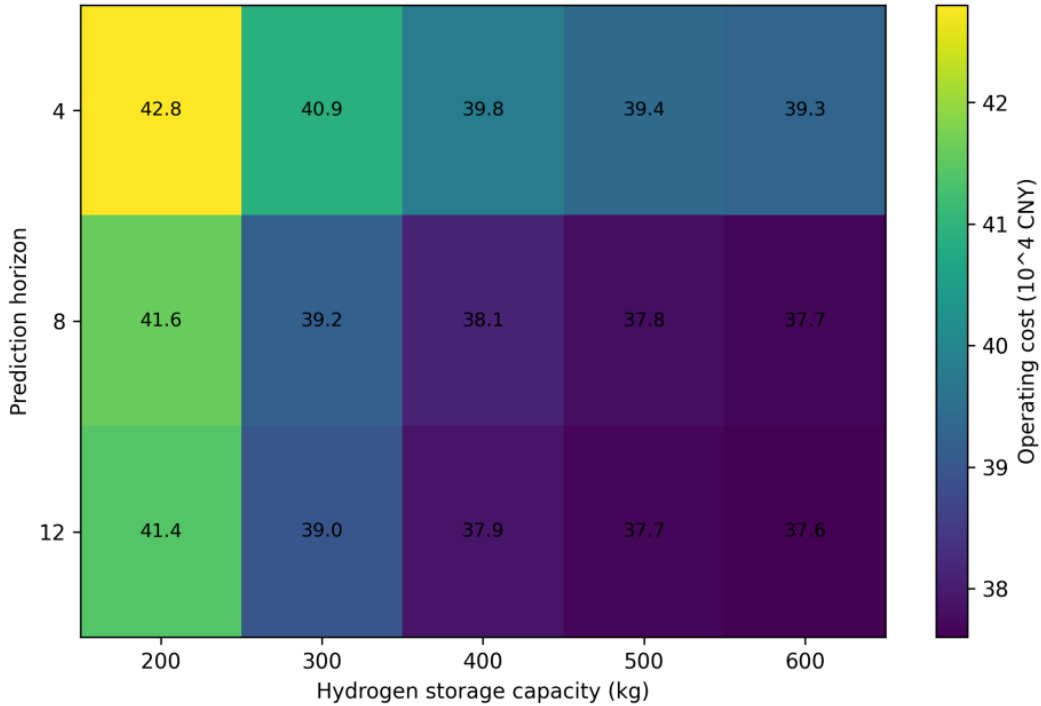


Figure 8: Plot of integrated operating cost change for different hydrogen storage capacity and MPC prediction step size

The effect of MPC parameters on the results is also characterized by stages. The results shown in Table 6 show that when the hydrogen storage capacity is fixed at 400 kg, the prediction step is increased from 4 to 8, the comprehensive operation cost is reduced from 398 thousand yuan to 381 thousand yuan, the reliability rate of power supply is increased from 99.18% to 99.36%, and the average power deviation is reduced from 4.1% to 3.8%. It shows that the short prediction window is difficult to fully identify the power gap and hydrogen storage call demand in the subsequent period, and it is easy to make the control strategy biased to local correction. When the prediction step size continues to increase to 12, the cost further decreases to 379,000 yuan, and the reliability rate increases to 99.37%, but the improvement has been significantly reduced, and the average single-step solution time increases from 1.38 s to 2.16 s. It can be seen that although too long prediction time domain can enhance the forward-looking, it will increase the burden of online solution, which is not conducive to real-time deployment.

Table 6: Sensitivity results between hydrogen storage configuration parameters and MPC control parameters

Group	Hydrogen Storage Capacity (kg)	Prediction Horizon	Total Operating Cost (10,000 CNY)	Power Supply Reliability (%)	Average Power Deviation (%)	Average Single-Step Solution Time (s)
S1	200	8	41.6	99.11	4.4	1.32
S2	400	8	38.1	99.36	3.8	1.38
S3	600	8	37.7	99.37	3.8	1.41
M1	400	4	39.8	99.18	4.1	0.87
M2	400	8	38.1	99.36	3.8	1.38
M3	400	12	37.9	99.37	3.7	2.16

From the perspective of synergy, the hydrogen storage capacity and MPC parameters are not independent of each other. When the hydrogen storage space is small, the long prediction window lacks enough hydrogen storage to effectively compensate even if the subsequent gap is identified in advance. When the hydrogen storage capacity is large and the prediction window is too short, the system is difficult to give full play to the intertemporal adjustment advantage of hydrogen storage resources. Considering the cost, reliability rate, power deviation and solution efficiency, the hydrogen storage capacity of 400-500 kg with the 8-step prediction window shows a good balance, which can not only maintain high new energy consumption and power supply reliability, but also control the online solution time within the acceptable range of the project. This result indicates that the parameter design of real-time hydrogen energy scheduling cannot only pursue the optimization of a single index, but should seek a coordinated match between the energy storage scale and the control foresight.

5.4 Discussion

Based on the above experimental results, it can be seen that after the participation of hydrogen energy, the real-time scheduling performance of the new power system is not only improved on a single index, but forms a more coordinated improvement relationship between new energy consumption, operating cost, power supply reliability and dynamic tracking accuracy. Compared with the conventional rolling scheduling, the proposed method reduces the wind and light abandonment rate by 18.7% on average, reduces the comprehensive operating cost by 12.4%, increases the reliability rate of the system power supply to 99.36%, and controls the average power deviation under load disturbance scenarios within 3.8%. This shows that after the linkage of hydrogen storage and MPC, the original decentralized processes of excess power absorption, inter-period energy transfer and gap compensation can be compressed into a unified online decision-making chain, thereby enhancing the real-time adaptation ability of the system to volatility and uncertainty.

The key to this result is that the electrolyzer, hydrogen storage unit and fuel cell are not called in isolation, but realize sequential linkage under the synergy of short-term prediction, state estimation and rolling optimization solution. The electrolyzer assumes flexible load absorption during the period of new energy surplus, the hydrogen storage device provides a cross-cycle buffer, and the fuel cell quickly feeds back to the grid in the net load lifting stage. The three jointly weaken the dependence of the traditional peak shading method on the depth climbing of the conventional unit. At the same time, MPC continuously introduces the latest observation to modify the future control sequence, which suppresses the cumulative amplification of prediction error in consecutive periods, and makes the scheduling scheme both executable and stable. However, the model in this paper still has some limitations. First, the parameter setting is mainly based on typical daily scenarios, which does not cover seasonal fluctuations and extreme fault disturbances in longer periods. Secondly, although the single-step solving time has been controlled within the engineering acceptable range by online optimization, the computational burden may still rise when the system node scale and constraint dimension are further expanded. Thirdly, the factors such as efficiency attenuation, start-stop loss and market price fluctuation of hydrogen storage equipment have not been fully explored. Nevertheless, according to the existing results, the proposed method has good engineering applicability, and can provide a computable analysis framework for real-time dispatching, reliability evaluation and digital operation of new power systems containing hydrogen.

6 Conclusion

Aiming at the problems of increasing fluctuation of new energy output, increasing difficulty of real-time balancing and stricter reliability constraints in the new power system, this paper constructs a hydrogen-electric coupling operation and evaluation framework, which integrates electrolyzer, hydrogen storage unit and fuel cell into a unified state space, and realizes rolling optimization scheduling combined with model predictive control. At the same time, the energy supply adequacy, load reduction rate and equipment availability are introduced into the reliability analysis process, forming a closed-loop analysis path of "online decision-result output-reliability feedback".

(1) In this paper, a hydrogen-electric coupling model for real-time scheduling is established, which unifies the new energy output, load fluctuation, hydrogen storage state and equipment operation boundary into a computable framework, and provides a model basis for the online call of hydrogen energy resources in the new power system.

(2) The experimental results show that the proposed method can effectively improve the comprehensive operation performance of the system. Compared with the conventional rolling scheduling, the average wind and light abandonment rate under the three types of working conditions is reduced by 18.7%, and the integrated operating cost is reduced by 12.4% on average. In the load disturbance scenario, the reliability rate of power supply reaches 99.36%, and the average power deviation is controlled within 3.8%, which shows that the cooperation of hydrogen energy and MPC has a significant support role in new energy consumption, dynamic balance and power supply security.

(3) This paper further shows that there is an obvious synergistic relationship between the hydrogen storage configuration parameters and MPC control parameters, and a moderate hydrogen storage capacity configuration and a reasonable prediction time domain length are more conducive to balance the economy, real-time performance and reliability. Subsequent research can be continued to expand under the conditions of extreme weather disturbances, long-cycle operation and coupling of market mechanisms, so as to improve the applicability of the model in complex engineering scenarios.

Author's Profile

Hu Fang was born in Qianjiang, Hubei. He is a hydrogen energy project expert at SINOPEC STAR Petroleum Co., Ltd., China. Focusing on renewable energy-powered water electrolysis hydrogen production control systems and hydrogen energy application research, he has participated in the whole process of planning, construction and operation of the SINOPEC Xinjiang Kuqa Green Hydrogen Demonstration Project.

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