A Systematic Multi-Time Scale Solution for Regional Power Grid Operation

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Abstract. Many aspects need to be taken into consideration in a regional grid while making schedule plans. In this paper, a systematic multi-time scale solution for regional power grid operation considering large scale renewable energy integration and Ultra High Voltage (UHV) power transmission is proposed. In the time scale aspect, we discuss the problem from month, week, day-ahead, within-day to day-behind, and the system also contains multiple generator types including thermal units, hydro-plants, wind turbines and pumped storage stations. The 9 subsystems of the scheduling system are described, and their functions and relationships are elaborated. The proposed system has been constructed in a provincial power grid in Central China, and the operation results further verified the effectiveness of the system.

1.Introduction

In the power dispatch department of a regional grid, there are many problems need to be considered while making schedule plans. Generally, there are mainly 4 concerns need to be taken into account:

The targets

The plan needs to focus on the schedule targets, in order to solve all the potential problems that may appear during operation. Usually, the objectives are different for problems with different time scales or considering different stations of the grid.

Time scales

We usually concern on different problems with the time scale of scheduling varies. Take wind power forecast as an example, the target and mathematical models can be very different considering different time scales, the accuracy of mid-long term forecast may be much worse than that of short-term forecast, and the result need to be corrected.

The objects

In a schedule plan, the objects are various type of sources, including thermal units, hydro-plants, wind turbines, all sorts of energy storage stations and other sources such as the integration of Ultra High Voltage (UHV). How to take advantages of their characteristics respectively and make a maximum coordination effect, has always been a research focus.

Grid status

In a schedule plan, different grid situations must be concerned. Reference [1] proposes the classical power system model consisting of three operating states. Different scheduling strategies need to be made in respond to these states.

The basic idea focusing on the questions above is decomposition. For example, control strategies with time-scale decomposition are widely used in many areas, such as power control system[2] and micro-grid operation[3]. In this

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paper, the entire schedule system in a regional grid is decomposed into 9 subsystems, solving problems focused on different time-scales and different grid operation status, trying to solve the problems introduced by the integration of large scale renewable energy sources and the UHV transmission.

This paper is organized as follows: Section II introduces the framework of the schedule system, and the detailed description of the 9 subsystems is given in Section III. Section IV concludes the work of the paper..

2. THE FRAMEWORK OF THE SCHEDULE SYSTEM

The framework of the proposed schedule system is shown in Fig. 1. It mainly consists of 9 subsystems, focusing on 9 sub-problems. The subsystems are listed below: 1) Economical storage strategy of thermal coal. 2) Analysis of peaking margin and strategy. 3) Intelligent scheduling of multi-type generators. 4) Wind power forecast based on multiple time scales. (Including middle-term, short-term and ultra-short-term forecast). 5) Automatic generation control (AGC), automatic voltage control (AVC), and their coordination control. 6) Synchronization and control of wind turbines. 7) Evaluation of the ability of primary and secondary frequency regulation. 8) Preventive control strategy and emergency control strategy. 9) Index system of evaluation on optimized operation.

These 9 subsystems form the framework of the schedule system. They solve the problems including forecast, control, dispatch and evaluation, through time scales from month, week, day-ahead, within-day to day-behind, considering various type of sources and concerning strategies under different grid stations. The system can also be used in regional grids with different backgrounds, such as grids with the integration of UHV.

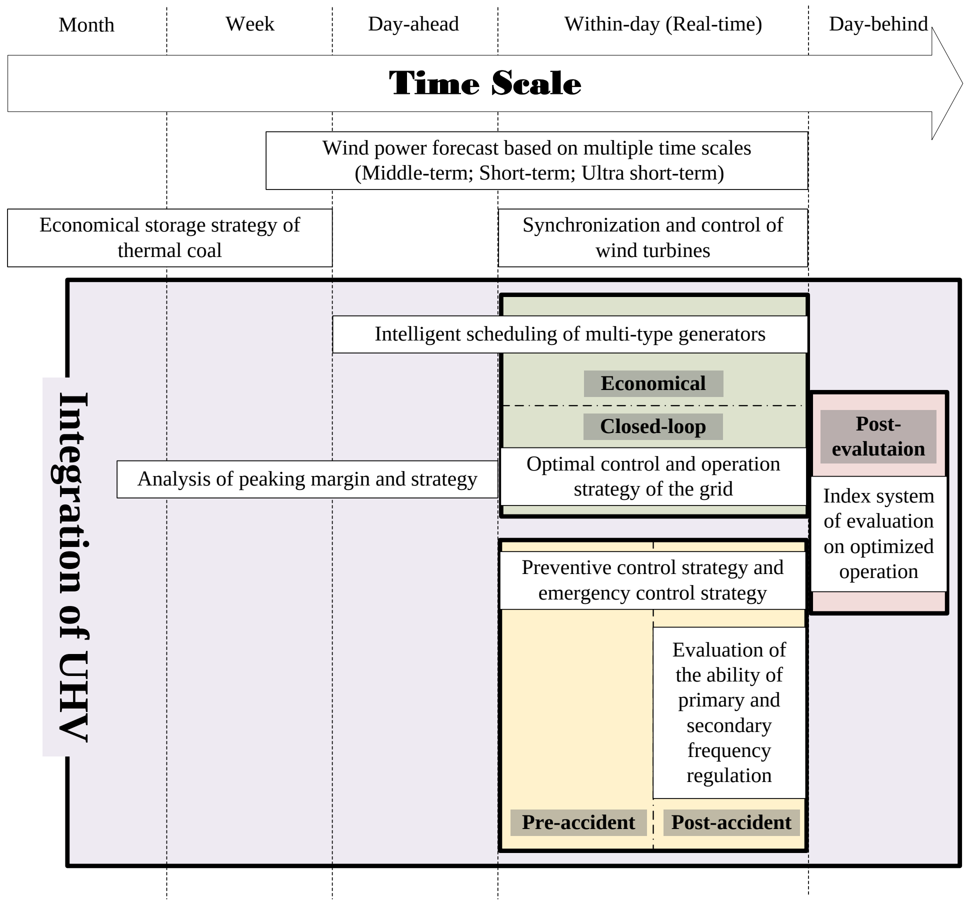

Figure 1.The framework of the schedule system

3.THE DETAILED DESCRIPTION OF THE SUBSYSTEMS

This part explains the detailed models and strategies of the 9 subsystems.

A. Economical Storage Strategy of Thermal Coal[4]

Storage strategy of thermal coal need to be made in a mid-long term schedule plan, to meet the need of thermal power generation.

The strategy consists of 3 parts: 1) Forecast of thermal coal, 3) Storage strategy of thermal coal, 2) Forewarning index of thermal coal.

1) Forecast of thermal coal

In this part, an indirect forecast method is proposed. First, a forecast of the whole consumption in the regional grid is calculated. Then a forecast of uncertain thermal generation is made, under different factors such as runoff, also taking into consideration the fluctuation of other clean energies.

2) Storage strategy of thermal coal

The storage strategy is decomposed into two parts: daily storage and safe storage. Daily storage ensures the daily thermal generation, which can be calculated through daily schedule. Safe storage avoids the supply gap in case of sudden increase of consumption or failure in coal supply.

3) Forewarning index of thermal coal

A forewarning index system is needed to dynamically evaluate the effectiveness of the storage strategy, and give forewarning before the stock reaches the margin. In terms of levels, the indices can be divided into coal supply index, coal consumption index, and coal storage index. In terms of spatial scales, the indices can be divided into plant storage index and regional storage index.

B. Analysis of Peaking Margin And Strategy[5]

In this subsystem, the operation scheme is examined to check if the peaking demand is met.

A decoupled peaking model is proposed in this subsystem to make a coordinated peaking plan for multi-type generators. The flowchart of the decoupled model is shown in Fig. 2.

In this model, a bi-level sub-model for thermal units is used to introduce deep peaking and give the start-stop peaking capacity of thermal units under different load peaks and valleys.

From the distribution map of peaking capacity, the peaking margin can be given and the operation strategy can be revised.

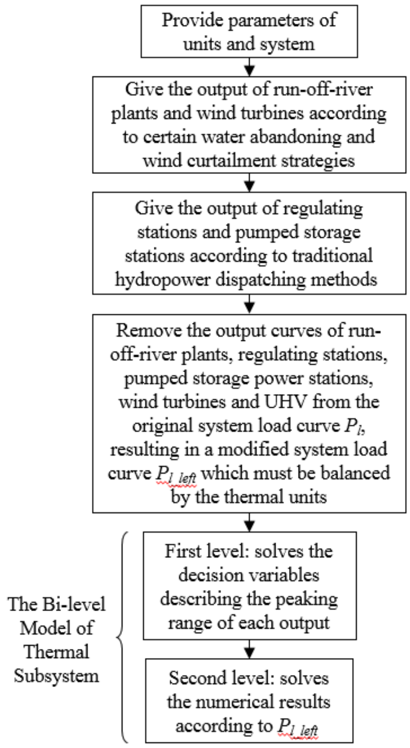

Figure 2.The flowchart of the decoupled peaking model

C. Intelligent Scheduling of Multi-type Generators[6]

This part is the major part of the whole system. In this part, multi time-scale multi power-type joint optimal scheduling approach is proposed. The basic scheme is shown in Fig.3. The schedules should consider the constraints of the whole system, including characteristics and functions of multi-type generators and systematical-level operating constraints, and then minimize the considered objective function, such as economic index, environmental index, and efficiency index[7].

Due to the complexity of this joint optimal scheduling problem and the requirement of practical operation, solving method should meet the need of rapidity, accuracy and practicability. Usually, improved intelligent algorithms (such as GA, PSO) can be used, especially in schedule plans with problems of unit commitment.

D. Wind Power Forecast Based on Multiple Time Scales[8]

Due to the characteristics of uncertainty, the forecast of wind power need to be focused. Wind power forecast has been researched much by many researchers. But in a regional grid, special concerns need to be taken. First, the forecast need to take into account the spatial correlation between different anemology stations. Second, the forecast should be decomposed into multiple time scales, to meet the need of different schedule plans with a series of time spans.

The model also uses the genetic algorithm and BP neural network, training the input data to output data, to satisfy the mapping relationship based on the historical data.

The framework of the subsystem is shown in Fig. 4.

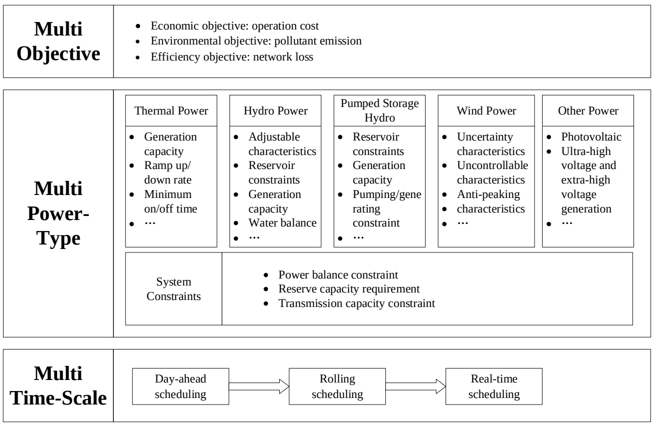

Figure 3.The scheme of multi time-scale multi power-type joint optimal scheduling

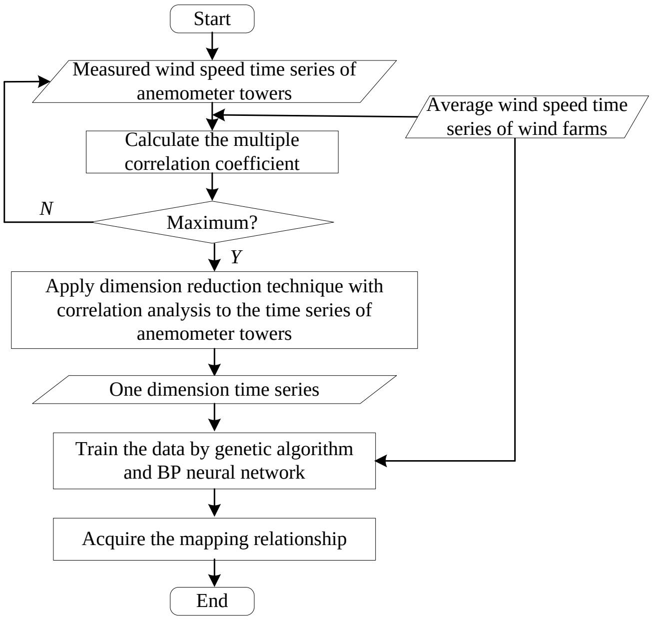

Figure 4.The flow chart of wind power forecast with consideration of the relationship of multiple temporal and spatial scales

E. AGC, AVC, And Their Coordination Control

In a running regional grid, Auto Generation Control (AGC) controls the active outputs of the generators, plays an important part in secondary frequency regulation and economic dispatch, while Auto Voltage Control (AVC) regulates the generator voltage. The coordination control model takes both the active power and voltage of the generators as control variables, to achieve the target of coordinative control.

The model takes economy, safety and quality as the targets. In practical terms, the objectives are transmission losses, reactive power balance, voltage deviation of hubs, and tie-line load bias.

The framework of the subsystem is shown in Fig. 5.

The coordinative control model realizes the closed-loop real-time schedule of the grid.

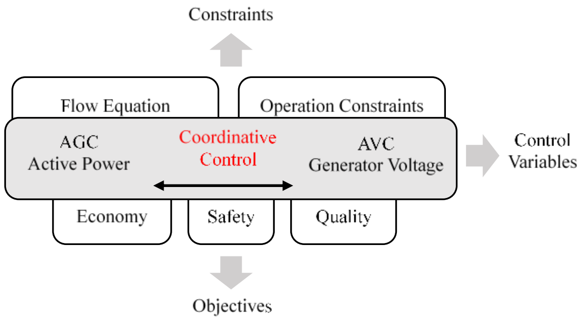

Figure5. The framework of the coordinative control model of AGC and AVC

F. Synchronization And Control of Wind Turbines

In the previous part, real-time control of regular generators is realized. But in a regional grid with high wind penetration rate, synchronization and control of wind turbines need to be considered specially. More efficient control strategy focused on the fluctuations and intermittency of wind power is needed.

In this subsystem, a probabilistic model is proposed to evaluate the influence of the characteristics of wind power on the operation of the grid. Based on the model, the control strategy is proposed. Some of the brief analysis is listed below.

1) Power balance

The fluctuation and uncertainty of wind power will have a great impact on power balance.

2) Voltage and reactive power control

Reactive power compensation equipment such as SVC, SVG, etc. can optimize the reactive power output to achieve the voltage of every bus within a reasonable range

3) Information and communication

The subsystem can report the operative status of wind turbines to the dispatch department, issuing the turbines to follow the scheduling target with consideration both various security constraints and economic benefits.

G. Evaluation of The Ability of Primary And Secondary Frequency Regulation[9]

Primary and secondary frequency regulation are important control means when the grid encounters a frequency deviation. The ability of frequency regulation depends on both the unit regulation performances and regulation strategy. An objective and comprehensive evaluation can make the grid more observable and controllable, and improve the grid’s ability on dealing with sudden load change.

In this subsystem, an online assessment method for AGC regulation based on WAMS is proposed. Firstly, we put forwards the assessment index system which integrates the indices in time scale and state dimension, thus make a comprehensive appraisal for AGC units. Then responding to the high sampling rate and high precision character of WAMS data, the control process of AGC regulation is divided into three segments: fast segment, assessment segment and time-out segment. Different methods are applied in different segments, so the calculation amounts and data storage can be efficiently declined to meet the requirements of online evaluation. The flowchart of the assessment algorithm is shown in Fig. 6.

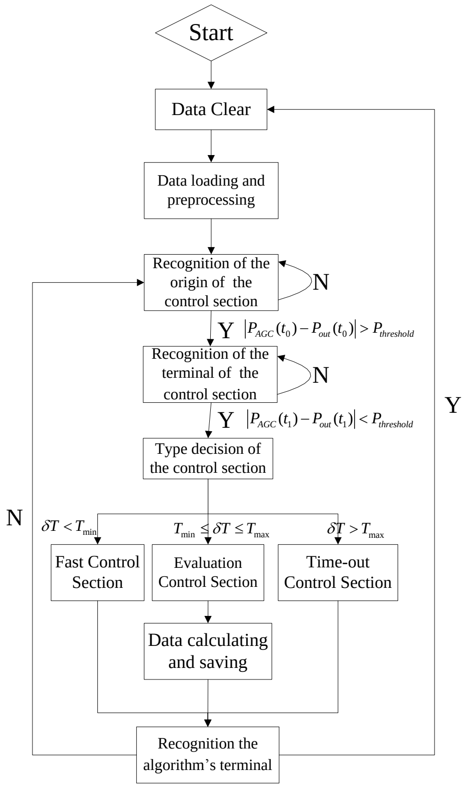

Figure 6 The flowchart of the decoupled peaking model

The evaluation system has been applied in provincial Power Grid and the results verify the feasibility and efficiency of proposed method.

H. Preventive and Emergency Control Strategy[10][11]

Guaranteeing safe and stable operation of the power system is an important goal for grid companies, and accomplishing this goal is of great importance to the development of economy together with people's lives. With the presentation of renewable energy generation and UHV technology, old weak links of the grid will be changed for the access of the UHV lines, and new weak links will also be shown. As a consequence, testing the network again and decide new controlling strategies will be a priority for grid companies. Based on weak links obtained from the PSASP data of a grid for the summer in 2015, the risk theory is used to study the cooperative control strategies of preventive control and emergency control in order to solve the overload problems, power angle problems and voltage problems. Some of the brief analysis is listed below.

1) Get the potential weak links

All the potential weak links have been checked using the PSASP planning data of Hunan grid for the summer in 2015, then the weak links of the provincial grid under the new condition have been obtained. By analyzing the results, overload problems, power-angle stability problems and voltage stability problems have been chosen to solve.

2) Solution to the overload problem

The risk equation describes the overload of UHV is set up to be the objective function. Time-domain simulation method and analysis method have been used to look for numerical relationships between the quantities of preventive control and emergency control. The restrictions of preventive control variables are decided according to the load shedding proportion regulations for different areas in Rule 599. The quantity of preventive control and emergency control are obtained when the objective function achieve its minimum value.

3) Solution to the power-angle stability problem

The risk equation describes power-angle stability problems in this grid is set up to be the objective function. Time-domain simulation method and polynomial fitting method have been used to look for numerical relationships between the quantities of preventive control and emergency control. The restrictions of preventive control variables are decided under the condition that the capacity which are decided to be shut down before and after a fault must be no less than the capacity of the whole power plant. The quantity of preventive control and emergency control are obtained when the objective function achieve its minimum value.

4) Solution to the voltage stability problem

The risk equation describes voltage stability problems in this grid is set up to be the objective function. Time-domain simulation method and polynomial fitting method have been used to look for numerical relationships between the quantities of preventive control and emergency control. The restrictions of preventive control variables are decided according to the load shedding proportion regulations for different areas in Rule 599. The quantity of preventive control and emergency control are obtained when the objective function achieve its minimum value.

I. Index System of Evaluation on Operation[12]

In order to assess the power grid's daily operation result, an assessment index system for power grid's daily operation is proposed and the assessment method is discussed in this subsystem. Firstly, based on general construction principles of an assessment index system, a three-level assessment index system is designed in consideration of the power grid's operation needs in aspects of security, economy, equity and environmental friendliness. This medium-sized index system can fully reflect the power grid's daily operation. As for index integration, Analytic Hierarchy Process (AHP) is used to determine the weight of each index, and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is used to integrate the index in consideration of the real needs of the operators, and the practical steps of this method are also discussed. Finally, the whole index system is visualized using a radar map, to reflect the everyday situation of schedule and operation of the regional grid comprehensively. Case study results show that the proposed method can evaluate the power grid's daily operation. This assessment system can be used for comparison of the power grid's daily operation results, and provide guidance for optimal operation of power grids.

4.SUMMARY

In this paper, a schedule system for provincial power grid based on multi-time scale is proposed to deal with the problems the grid faced with the presence of large scale renewable energy resources and the integration of UHV. A systematic scheme framework with 9 different subsystems is presented in this paper. Detailed description of each subsystem is also given. The proposed schedule system has been constructed in a provincial power grid in Central China, and the operation results further verified the effectiveness of the system.

5.ACKNOWLEDGEMENTS

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