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Energy Internet System Based on Static Security Analysis of Multi-Energy Flow

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Abstract: The proposal of the energy internet system has set off a new wave of energy reform. The integrated energy system is an important physical energy carrier of the Internet, including energy conversion, distribution and organic coordination. The purpose of this work is to study and analyze the energy network system, and to preliminarily study the steady-state modeling of the energy network system. The physical model of the Internet energy system is analyzed, and the steady-state model of the Internet energy system including the power system and the thermal system is established. Secondly, the static safety analysis of the multi-energy flow of the energy grid system is carried out. The power flow calculation results of the power system show that there is a certain difference in the settlement results between the mutual aid control method and the protection control method. Node D changes from a PV node to a balanced node, the voltage amplitude remains the same, both 1.04 p.u., and the phase angle changes, from 0 to -0.1465. The energy flow calculation results show that the gas pressure also changes in the two control modes. The pressure of node 2 changes from a constant-flow gas source node to a balance node, and the pressure of node 4 is a balance node in both control modes. The pressure remains unchanged and changes, and the energy transmission power of the two subsystems decreases.

1. Introduction

The interweaving of energy security issues, environmental pollution issues and climate warming issues has led to major changes in people's energy consumption structure and utilization methods. How to combine the advantages of distributed and digital technologies, give full play to the potential of renewable clean energy and break the traditional single and isolated energy supply form, comprehensively optimize the traditional energy production mode and structure, promote the transformation of the energy system, and build a A modern energy system that is cleaner, environmentally friendly, safe, reliable, efficient and intelligent is a common topic that is widely concerned by the international community [1]. At present, there are three main problems in my country's energy system that need to be focused on: the immature, high-quality, effective, and flexible energy supply methods, low energy management efficiency, and low-carbon environmental protection issues. Electric energy and thermal energy are the most important forms of final energy consumption. With the increasing demand for electricity, the high-quality development of the power industry is imminent. It plays the role of the main body and the pusher in the energy system [2].

Since the concept of Energy Internet was put forward, domestic and foreign experts and scholars have actively carried out beneficial exploration and research on Energy Internet. Bhuiyan M proposed that security assessment has changed from a deterministic approach to a risk-based approach, which is divided into two categories: risk assessment and risk identification. First, risk assessment is discussed in detail, summarizing different approaches to address the problems of equipment failure probability modeling, scenario formulation, and severity assessment. In addition, complete risk identification research and perspectives are provided as a roadmap for identifying immediate risk sources. Risk identification technologies such as monitoring methods, sensitivity analysis, and risk identification help operators take effective preventive measures to restore system security [3]. The Ranise S role resource access control model supports the specification and enforcement of various time constraints for role activation, role activation, and role time processes. This paper describes three mappings for storing solutions to a class of policy problems: they map security analysis problems with static effect time conditions to problems without them. Demonstrates how to use mapping to extend the functionality of an application to analyze access control policies that manage time effects based on time effect patterns. Experimental evaluations using design implementations show that one proposed graph performs better than the other two and is the first tool that can perform inference using real-time (static) detection time [4]. Ramreddy C. Analysis of the combined effects of thermal radiation and activation energy and chemical reactions on secondary convection in micropolar fluids on inclined plates. Convective thermal boundary conditions and suction/injection effects are taken into account for the inclined plate surface. The Boussinesq approximation and nonlinear (i.e. quadratic or nonlinear convection) and normal boundary layer assumptions are used in the mathematical formulation. Solving nonlinear governing equations by combining local inequalities and continuous linear processes [5]. Scholars at home and abroad have made great breakthroughs in the research of multi-energy flow static security analysis.

The energy Internet system includes flexible interactive links between multiple energy systems. It can integrate many call scheduling resources and cooperate with the access and operation of renewable energy, which increases the flexibility of the system, but also increases the operating risk of the system. and general management issues. To this end, fully implement the "multi-energy compatibility" feature of the Internet energy system, promote the integrated operation of the "grid-connected load" of each energy system, and realize multi-energy flow control and optimization. It is of great significance to maximize comprehensive benefits and promote the consumption of renewable energy, and its essence can be understood as the optimal scheduling and control of multi-energy flow networks. Therefore, multi-energy complementarity and multi-energy flow collaborative optimal management, as the technical core of the energy Internet system, have important research significance and huge engineering application value.

2. Research on Energy Internet System Based on Static Security Analysis of Multi-energy Flow

2.1. Energy Internet

The utilization of traditional fossil energy has not only reduced the production capacity of fossil energy, but also reduced the renewable energy, and has also put more and more pressure on the environment. More and more attention has been paid to energy supply and structural transformation on a global scale, and the energy Internet has emerged in this context. Energy Internet integrates Internet information technology and renewable energy, and provides a new energy structure and supply mode for sustainable energy development and low-carbon, clean and efficient utilization [6-7].

2.2. Static Security Analysis Process

(1) Anticipated failure analysis

The premise of the so-called predictive failure analysis is that there are expected objects. Generally, the expected objects are the various components of the power system that have been constructed. The expected failure analysis is to combine and arrange the possible failures in these parts to determine the probability of failure and once a failure occurs. What kind of damage will it bring to the system [8-9].

(2) Definition of expected failure

Due to the enhancement of the security strength of the power grid, most of the power grid components have basically not posed a major security threat to the power grid system; and a very small number of components that have a security threat to the power grid structure have also been known to the public. Therefore, a method of using fault set is proposed to replace the N-1 scanning method, and the fault system is consulted by some experienced front-line personnel. It includes some possible errors, and combinations of users can trigger groups of errors that are of interest to analysis and calculations. Error system is also known as all errors. All error groups in All Errors are enabled by default, and each error is individually set to Disabled. Only active error groups are analyzed during error scanning [10-11].

(3) Fault scanning

Some errors in the error system must be made before error scanning and can be divided into two categories: Malicious errors with adverse effects, which can only be checked after information analysis. The goal is to minimize unnecessary losses and analyze failures as quickly as possible. The aim is to eliminate the most "harmless" bugs in a short period of time and without missing any vulnerabilities [12-13].

(4) Detailed analysis of faults

In the process of troubleshooting, firstly, the failures that have no effect on the system should be checked out, and the failures that have adverse effects should be retained. In order to be able to determine the scope and extent of damage caused by the failure, the results also need to be carefully analyzed and calculated. The full power flow analysis starts from the grid-connected analysis, forms the admittance matrix, and iteratively corrects the full AC power flow. This analysis has the highest precision and can correctly obtain the specific factors of all components in the network [14-15].

2.3. Current Situation of Multi-energy Flow Solution

The integration of multiple energy streams is the key feature that distinguishes the Internet energy system from traditional independent energy sources (electricity/heat/gas). Energy optimization management [16-17]. The modeling and simulation of energy installation structures or energy systems is well established. The development of CCHP technology has led to an increase in the integration of thermoelectric networks. At the same time, with the development of various energy conversion technologies (such as electricity-to-gas, new energy power generation, etc.) and the increase in the form of energy use in recent years, there are more and more types of energy equipment, and moderate improvements have been made. Due to the differences in the characteristics and integration efficiency of different power flows, finding an efficient and unified multi-step solution algorithm is still a challenge, and multi-power flow fusion solutions and automation tools have not yet been established [18].

3. Model and Research of Energy Internet System Based on Multi-energy Flow Static Security Analysis

3.1. System Introduction

In this paper, the static safety of N-1 is analyzed by taking the IES (hereinafter referred to as the IES-4 conference system) including the IEEE-4 components of the power system, 10 components of the natural gas system and mixed components as an example. Install the P2G module to connect to Phase 1 of the gas system. The outputs of the coupling elements in the two control modes are shown in Table 1.

Table 1. Coupling element output

Name	Coupling element power (MW)	
	Mutual control mode	Protection control mode
P2G	130.645	200
MTl	200	200
MT2	189.153	200

The multi-energy flow calculation of IES-4 shows that when the coupling elements change from the protection control mode to the mutual aid control mode, the output of the elements decreases obviously, and the energy exchange power between the systems decreases. Among them, the P2G power drops by 34%, the MT2 power drops by 10%, and the rest of the changes are balanced by the balance node. The change of component power reflects that the two calculation methods proposed in this paper are both decoupling algorithms, but due to the different nature of the nodes connecting the subsystems, the calculated powers are obviously different.

3.2. Energy Flow Model of Energy Internet System

(1) Power system energy flow model

In the power system part of the energy Internet system, the conventional power flow model is still used as the energy flow model to realize the solution of the operating state of the power subsystem, as shown in Equation 1.

$$\begin{cases} P_i = V_i \sum_{j \in I} V_J (G_{ij} \cos\theta_{ij} + jB_{ij} \sin\theta_{ij}) \\ Q_i = V_i \sum_{j \in I} V_J (G_{ij} \sin\theta_{ij} - jB_{ij} \cos\theta_{ij}) \end{cases} \quad (1)$$

(2) Energy flow model of thermal system

The energy flow mathematical model of the thermal system part of the energy internet system is shown in Equation 2, which are the thermal power balance equation, pressure loss equation, heating temperature equation and heat recovery temperature equation of the thermal system, respectively.

$$\begin{cases} \mathrm{C_p} A_h m(T_s - T_0) - \Phi_L = 0 \\ \mathrm{BKm|m|} = 0 \\ \mathrm{C_s} T_{s,load} - b_s = 0 \\ \mathrm{C_r} T_{r,load} - b_r = 0 \end{cases} \quad (2)$$

In the formula, Ah represents the relationship matrix of the thermal system node pipeline; Cp represents the specific heat capacity, in MJ/(kg.K); m represents the hot water flow in the pipeline, in kg/s; Ts represents the heating temperature of the thermal system node, and T0 represents the thermal power The outlet temperature of the system node is all in °C, ΦL represents the thermal load power of the thermal system node, the unit is MW, B represents the parallel loop correlation matrix of the thermal system; K represents the resistivity of the heat pipe; Cs, Cr, bs, br represent and Matrix and vector of coefficients related to the heating or reheating temperature.

3.3. Decision Tree Algorithm

(1) ID3 algorithm/information entropy

The principle of ID3 algorithm is to use information gain as the criterion for feature division. "Information entropy" is a common measure of the purity of selected samples. For example, given a set D with multiple samples, the ratio of sample type k to the total sample type is calculated as pk, then the information entropy of sample set D is defined as:

$$Ent(D) = -\sum_{k=1}^{y} p_k \log_2 p_k \quad (3)$$

(2) C4.5 algorithm/gain rate

A problem with the ID3 algorithm is that it is biased towards features with a large number of values. For example, if there is a unique identifier, the sample set D will be split into branches |D| and only one sample per branch will go through this split with zero information entropy, very clean, but not useful for classification. Therefore, the C4.5 algorithm adopts the "gain ratio" to select the partition features, which avoids the problems caused by this problem. Candidate features with above-average information gain are first calculated using the ID3 algorithm, and then C4.5 is used to calculate the percentage gain of these candidate features. The gain rate is defined as:

$$Gain\_ratio(D,a) = \frac{Gain(D,a)}{IV(a)} \quad (4)$$

4. Analysis and Research of Energy Internet System Based on Multi-energy Flow Static Security Analysis

4.1. Power Flow Calculation Results of Power System

The power flow calculation results of the power system in IES-4 are shown in Table 2. Compared with the mutual aid control mode, the voltage amplitude of node g3 in the protection control mode is increased, mainly due to the reduction of the P2G output.

Table 2. Power system voltage in two control modes

Node number	Voltage (p.u.)		Phase angle (°)	
	Mutual control mode	Protection control mode	Mutual control mode	Protection control mode
A	0.9981	0.9964	0.0001	0.0002
B	0.9984	0.9946	-0.7685	-0.8467
C	0.9721	0.9678	-1.4567	-2.4587
D	1.04	1.04	0	-0.1465

There is a certain difference in the settlement results of the two modes. Node D changes from a PV node to a balanced node, the voltage amplitude remains unchanged, both are 1.04p.u., and the phase angle changes, from 0 to -0.1465.

Table 3. Power system flow in two control modes

Branch head	Branch end	Active power (mw)		Reactive power (mvar)	
		Mutual control mode	Protection control mode	Mutual control mode	Protection control mode
A	B	25.4688	27.6674	-5.5679	-6.5369
A	C	77.5642	124.5689	52.1452	55.5146
B	D	-45.8756	-43.1587	-53.4598	-43.5654
C	D	-52.4895	-77.4521	-56.4568	-66.1548

The power flow of all branches of the power system has changed. It can be seen from Table 3 that in the mutual economic control mode, except for the power of MT1, the power of other coupling elements and the power of the balance node of the power system have changed.

4.2. Calculation Results of Energy Flow in Natural Gas System

The calculation results of the natural gas system power flow in IES-4 are shown in Figure 1. The gas pressure has also changed in the two control modes. Node 2 has changed from a constant flow gas source node to a balanced node, and the pressure has dropped. Node 4 is in the two control modes. Both are equilibrium nodes, and the air pressure remains unchanged.

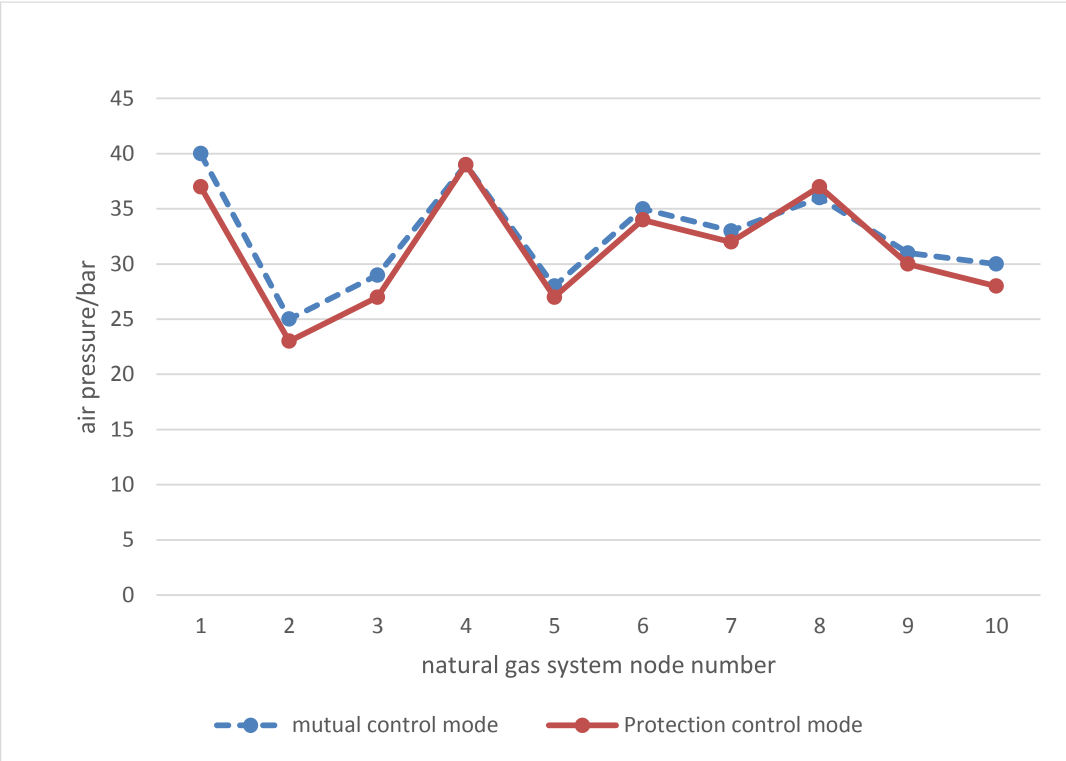

Figure 1. Comparison of IES-4 air pressure

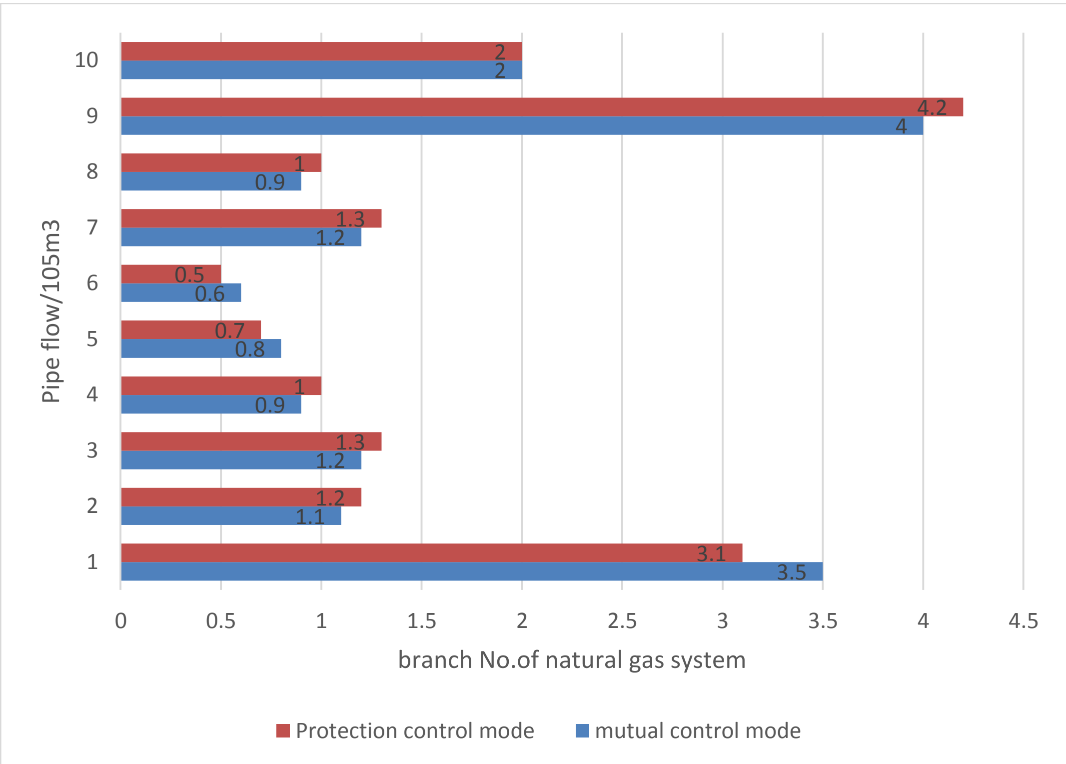

Figure 2. ES-4 pipeline flow comparison chart

According to the analysis in Figure 2, the control mode of the coupling element changes, and the type of nodes connected to the coupling element in the energy internet system changes, which leads to changes in the system energy flow. From the multi-energy flow calculation results of the IES-4 system.

5.Conclusion

In this paper, two control methods are proposed for the coupling elements in the power grid system, which have strong practicability in actual operation. The dispatcher can change the control method of the coupling element according to the load level of the integrated energy system to ensure the safe operation of the integrated energy system. The safe and stable operation of the energy Internet system is the basic guarantee for the realization of the energy transition goals. There are mature static security analysis methods, but the energy internet system has multiple heterogeneous energy sources and complex coupling relationships, which makes static security problems with multi-energy coupling characteristics. Traditional analysis methods are no longer used, and there is a lack of analysis of the impact of energy coupling in system accidents. The research on how to conduct static safety coupling analysis for integrated energy systems is of great significance.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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