Structural Modeling for the Comparison Indicators in Various Electricity Generating Systems

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1. Introduction

Comparison indicators of various power systems can be yielded by solving a multicriteria decision-making (MCDM) problem. In reality, there are different grades of interdependence among the decision elements (e.g., decision goal, decision criteria, and decision alternatives). In our previous work [1], based on an analytic hierarchy process (AHP) technique [2], an independence model was developed for the comparison indicators under the assumption that there is no interdependence among the decision elements. For handling different interdependence phenomena (e.g., independence, inner dependence, outer dependence, feedback effect, a combination thereof) among the decision elements, one of the simplest graph structures was investigated [3] on the basis of an analytic network process (ANP) technique [4].

In the present work, the main objective is to study an assessment model with a high grade of interactions among the decision elements. Comparison indicators (e.g., weighting factors, overall priority scores, and risk attitudes towards a nuclear power plant) for seven power generation systems are obtained.

2. Interdependence Modeling

Concerning the comprehensive assessment of different power sources with conflicting characteristic factors (or decision criteria), in general, a network approach in combination of a directed network structure (digraph) and a supermatrix theory can be applied. This approach has been known as a supermatrix approach or the ANP approach. One of several advantages of an ANP approach is able to deal with grades of interdependence (e.g., internal feedback effect, external feedback effect, inner dependence) among the decision elements.

According to the algorithm of the network model developed in a previous work [3], the interdependence model with a high grade of interactions is devised to aggregate risk attitudes (e.g., risk-loving, risk-averse, neutral attitudes) towards the risky facility such as a nuclear power plant.

Figure 1 shows the hierarchical network (or hiernet) structures under consideration. Here, decision alternatives cluster is composed of the conventional systems such as nuclear and fossil-fuelled (coal-fired, heavy oil-fired, LNG) as well as the renewable energy systems (hydropower, wind power, solar photovoltaic (PV) power). These seven options are evaluated in terms of eleven conflicting subcriteria. Criteria cluster consists of as follows: (1) the economic cluster represented by generation cost (GC) and land use (LU); (2) the environmental cluster by global warming (GW), acidification (AC), and energy payback (EP); (3) the social cluster by quality of life (QL), fuel/energy supply security (SS), protection of terror (PT), and sustainability degree (SD); and (4) the health cluster by accident mortality (AM) and years of lost life (YOLL).

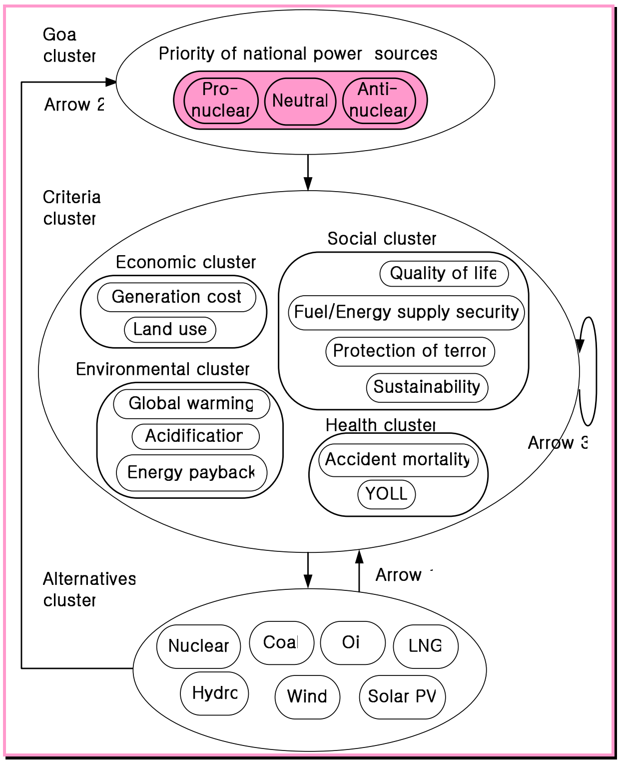

Figure 1. Hiernet structure for the interdependence model.

The goal cluster includes three types of risk attitudes towards a nuclear power plant: (1) a risk-loving attitude (i.e., a pro-nuclear attitude; agreement to accept nuclear energy-centered policies in the energy mix planning), (2) a risk-averse attitude (i.e., an anti-nuclear attitude; agreement to phase out and even to close operating nuclear power plants), (3) a neutral attitude (i.e., if necessary, nuclear energy will be accepted as power sources).

In Figure 1, the arrow 1 indicates an **internal** feedback effect of an alternative cluster on the criteria cluster, the arrow 2 an **external** feedback effect of an alternative cluster on the decision-makers(DMs)' attitude towards nuclear systems, and the arrow 3 an **inner** dependence of subcriteria in the criteria cluster. As shown in Figure 1, the interdependence phenomena with two feedback effects and one inner dependence are simultaneously taken into account in the present interdependence model.

3. Results and Discussion

According to opinions of ten energy experts who took part in this survey, subjective evidence is extracted through a pairwise comparison technique. Table 1 listed comparison indicators such as attitude weighting factors, criteria weighting factors, and overall scores for electricity generating systems.

Table 1. Comparison indicators for the interdependence model with two feedbacks and one inner dependence

viewpoint	1 pro-nuclear		0.47	1
	2 neutral		0.33	2
	3 anti-nuclear		0.20	3
criterion	Econ.	4 GC	0.1809	1
		5 LU	0.0477	9
	Env.	6 GW	0.0959	5
		7 AC	0.0618	8
		8 EP	0.0635	7
	Soc.	9 QL	0.1591	2
		10 SS	0.0406	10
		11 PT	0.0236	11
		12 SD	0.1378	3
	Heal.	13 AM	0.0754	6
		14 YOLL	0.1136	4
alternertive	15 nuclear		0.2261	1
	16 coal-fired		0.0987	5
	17 oil		0.0832	6
	18 LNG		0.1014	7
	19 hydropower		0.1851	2
	20 wind		0.178	3
	21 solar PV		0.1276	4

In the opinions of the expert group, it seems to infer that the nuclear system is preferred to the fossil or the renewables after aggregation of the three attitudes. The group shows the 47% degree of attitude towards pro-nuclear and regards the generation cost, quality of life, sustainability degree, and YOLL as the most important criteria in descending order.

In Table 1, overall scores as appropriateness indices for each attitude are listed. After aggregation of all attitudes, the nuclear power, the hydropower, the wind energy, and the solar PV are obtained in the descending order of preference.

4. Conclusion

An interdependence model with a high grade of interactions among decision elements including DMs' attitudes has been developed. In this work, two feedbacks and one dependence phenomena are investigated on the basis of the 10 experts energy group. It was found that the interdependence model yields (1) attitude weighting for the group decision-makers; (2) criteria weighting in view of the aggregated attitudes, and (3) system ranking of preference. In the near future, various degrees of interaction phenomena will be quantified.

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