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Effects of the Feedback Models on the Comparison Indicators for Power Systems

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1. Introduction

Comparative assessment of various power systems can be treated as a multicriteria decision-making (MCDM) problem. In reality, there is interdependence among the decision elements (e.g., decision goal, decision criteria, and decision alternatives). In our previous work [1], using an analytic network process (ANP) technique [2], a comprehensive assessment framework for power systems was developed only for the feedback effect, one of the interdependence phenomena (e.g., feedback effect, inner dependence, outer dependence, independence) among the decision elements. It is assumed in an independence model that there is no interdependence among the decision elements.

In the present work, the main objective is to investgate effects of the assessment models on comparison indicators (e.g., weighting factors, overall scores) for several power generation systems. Moreover, the risk attitudes of the decision-makers towards a nuclear power plant are incorporated into the point of view for the decision-makers (DMs).

2. Methods

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 matrix theory can be applied. This approach has been known as a supermatrix approach or the ANP approach.

An ANP technique deals with interdependence phenomena (e.g., feedback effect, inner dependence, outer dependence, independence) among the decision elements. The hierarchy structure corresponding to the independence model can be deduced from the digraph structure. It means that an AHP-based hierarchy model becomes a special case of the ANP-based network models. It should be noted that the hierarchy (i.e., AHP) models facilitate a benchmark process for the network models with various degrees of dependence.

Using the algorithm of the feedback model developed in a previous work [1], a case study is performed to investigate effects of different criteria sets on comparison indicators. The aggregation of the attitudes of the DMs (e.g., risk-loving, risk-averse, neutral attitudes) can be dealt with by using the feedback model.

3. Case study

Here, decision alternatives under consideration are the nuclear power system, the fossil-fuelled system represented by coal-fired power plant as conventional systems, and the solar photovoltaic (PV) system as a renewable energy source.

These three alternatives are assessed in terms of four conflicting criteria as follows: the economic dimension represented by the generation cost (GC), the environment by global warming (GW), the social by the degree of sustainability (DS), and the health by either years of lost life (YOLL) or accident mortality (AM).

The decision goal includes three types of risk attitudes towards the risk facility such as 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 neccesary, nuclear energy will be accepted as power sources).

3.1 Digraph model for criterion-set {GC,GW,DS,YOLL}

A feedback effect of an alternative cluster on the DMs' attitude towards power systems is taken into account. Figure 1 shows the hierarchical network (or hiernet) structures under consideration.

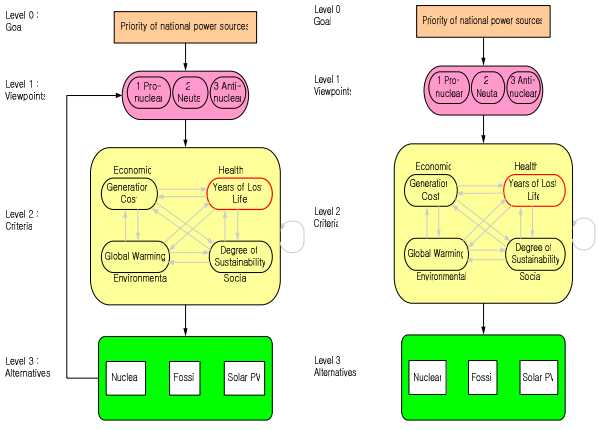

Figure 1. Hiernet structures for the {GC,GW,DS,YOLL}.

In Figure 1, the right part shows an independence model represented by a one-way directional tree structures (or hierarchy structure), whereas the left one is for the

feedback model by a network structure. As shown in Figure 1, the removal of the arc from level 2 to level 1 at the left figure leads to the right figure (a hierarchy structure without the feedback effect).

According to opinions of seven energy experts taken 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 appropriateness indices for power sources. These scores are obtained using the valuations (or utility) of power systems with respect to the criteria set {GC, GW, DS, YOLL}. In particular, the criterion YOLL is chosen as a representative one among health impacts.

Table 1. Overall scores of the feedback model for the criterion-set {GC,GW,DS,YOLL}

	Element	Score	Ranking
Attitude Cluster	1 Pro-nuc	0.4597	1
	2 Neutral	0.2227	3
	3 Anti-nuc	0.3176	2
Criteria Cluster	4 Economic	0.2691	2
	5 Environment	0.2613	3
	6 Social	0.1705	4
	7 Health(YOLL)	0.2991	1
System Cluster	8 Nuclear	0.5206	1
	9 Fossil	0.1926	3
	10 PV	0.2868	2

In the opinions of the expert group, it seems to infer that the nuclear system is preferred to the fossil or the PV after aggregation of the three attitudes. The group shows the 46% degree of attitude towards pro-nuclear and views the health aspect as the first line of importance.

In Table 2, appropriateness indices for each attitude are listed. For all attitudes, the nuclear power is preferred. The comparison of the feedback and independece models leads to the change of criteria importance.

Table 2. Overall scores of the independence model for the criterion-set {GC,GW,DS,YOLL}

Score (Ranking)	Attitude		
	1 Pro-nuc	2 Neutral	3 Anti-nuc
4 Economic	0.4088 (1)	0.2847 (2)	0.0560 (4)
5 Environment	0.1552 (3)	0.2999 (1)	0.3878 (1)
6 Social	0.1514 (4)	0.1388 (4)	0.2204 (3)
7 Health	0.2846 (2)	0.2766 (3)	0.3358 (2)
8 Nuclear	0.5334 (1)	0.5117 (1)	0.5084 (1)
9 Fossil	0.2538 (2)	0.1928 (3)	0.1038 (3)
10 PV	0.2128 (3)	0.2955 (2)	0.3878 (2)

3.2 Digraph model for the criterion-set {GC,GW,DS,AM}

Comparison indicators for power systems with respect to the criteria set {GC, GW, DS, AM} in a hiernet structure were yielded. The only difference from the above case is that, in particular, the criterion AM is chosen as a representative one among health impacts rather than YOLL.

According to Table 3, the health aspect has the most important weight 30%. Because it is assumed that the PV has near zero accident mortality, the one is preferable to the nuclear power, even though the goup has the largest pro-nuclear attitude. Thus, compared to Table 1, the criteria importance and the appropriateness index are influenced by the criteria set.

Table 3. Overall scores of the feedback model for the criterion-set {GC,GW,DS,AM}

	Element	Score	Ranking
Attitude Cluster	1 Pro-nuc	0.4020	1
	2 Neutral	0.2235	3
	3 Anti-nuc	0.3745	2
Criteria Cluster	4 Economic	0.2489	3
	5 Environment	0.2747	2
	6 Social	0.1744	4
	7 Health(AM)	0.3020	1
System Cluster	8 Nuclear	0.2940	2
	9 Fossil	0.1472	3
	10 PV	0.5588	1

Compared to Table 2, it is in Table 4 shown that the overall preference for each attitude has been influenced by the criteria sets.

Table 4. Overall scores of the independence model for the criterion-set {GC,GW,DS,AM}

Score (Ranking)	Attitude		
	1 Pro-nuc	2 Neutral	3 Anti-nuc
8 Nuclear	0.3212 (2)	0.3055 (2)	0.2580 (2)
9 Fossil	0.2192 (3)	0.1591 (3)	0.0629 (3)
10 PV	0.4596 (1)	0.5354 (1)	0.6791 (1)

4. Conclusion

An hiernet model including DMs' attitudes has been developed. In this work, the effects of criteion-sets on comparison indicators are investigated on the basis of the 7 experts energy group. It was found that the choice of either YOLL or AM in the health aspect has influence on (1) attitude weighting as well as criteria ranking for the feedback model; and on (2) system ranking for both models. In the near future, various inter-dependence models will be quantified.

Acknowledgement

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References

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