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Electrical Grid Conditioning For First NPP Integration, a Systems Engineering Approach Incorporating Quality Function Deployment

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1. Introduction

Nuclear power plant has a high potential to cause serious harm to environment as evidenced by effects of Fukushima and Chernobyl accidents. A reliable electrical power is required for a NPP to facilitate cooling after a shutdown. Failure of electrical power supply during shutdown increases core damage probability. Research shows that a total of 39% of LOOP related events in US are electrical grid centered [5]. In Korea, 38% and 29% of all events that led to NPP shutdown at Hanul units 3-6 and at Hanbit units 3-6 respectively were electrical related [1]. Electric grids for both operating and new NPPs must therefore be examined and upgraded for reliability improvement in order to enhance NPP safety.

2. Problem Definition

For countries developing first Nuclear power plant, electrical Grid upgrade is an important requirement to meet required grid reliability. The process of grid upgrade is both complex and expensive. Consideration of multiple factors such as generation, transmission, distribution, and loads in addition to coverage of large geographical areas makes the process complex and expensive. This paper proposes systems engineering methodology incorporating Quality Function Deployment (QFD) to the upgrade of electrical grid to manage complexity and minimize cost. The process involves customer requirements elicitation, Grid requirements definition and technical descriptors identification and ranking. QFD is used to model decision process by assigning weights and ranking technical descriptors while systems engineering is used to ensure that developmental risks are minimized. Conventionally, decision makers have relied only on engineering judgment which has resulted in expensive process. The methodology if employed will greatly reduce electrical grid improvement costs and hence enable poor countries planning to develop first NPP to do so within existing financial constraints. Figure 1 shows systems approach proposed in this paper.

3. Stakeholder identification.

A stakeholder is an individual with an interest in a system under development [3]. In the first stage Stakeholders are identified and categorized in groups based on level of interest, power of influence and appropriate method to manage their interests as shown in table1.

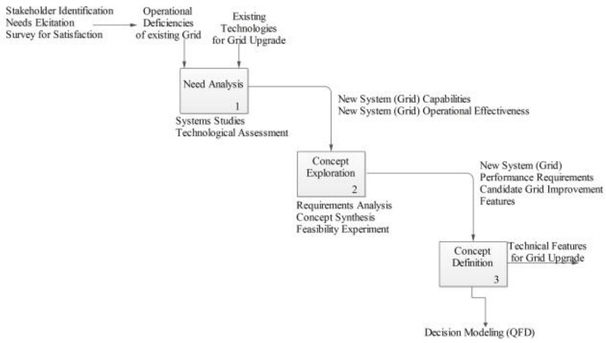

Fig.1. Systems process in grid upgrade

Table I: Stakeholder categorization

Stakeholder	Interest	Power	Manage
NPP Operator Company	High	High	Closely
Regulator	High	High	Closely
Major Consumers	High	High	Closely
Media	Low	High	Inform

4. Needs Analysis

Stakeholder needs are than elicited from stakeholders using focus groups, interviews and conferences. Table 2 shows sample stakeholder's needs.

Table II: Stakeholder needs

Stakeholder	Needs
NPP Operator Company and other major consumers	Stable Voltages
	Stable Frequencies
	Reliable supply
	No blackouts

5. Concept Exploration

This stage involves exploring alternative feasible concepts [4]. We identify grid technical Improvement requirements which will satisfy stakeholder requirements.

6. Concept Definition

This is a screenig process to select only those grid technical improvement requirements with a strong correlation with stakeholder requirements. An inter-relationship matrix is prepared between grid technical improvement requirements and stakeholder needs to identify their impacts stakeholder needs

Table III: Interrelationship matrix

Grid Technical Improvement Requirements	**Stakeholder Needs**						
	1	2	3	4	5	6	7
Redundancy	×	×	×	×			
New Generators	×	×	×	×	×	×	
Conductor Upgrade	×	×	×	×	×	×	×
Replace old Lines Equipment	×	×	×	×	×		×

The grid upgrade requirements with least or no strong causal relationship with stakeholder requirements are dropped from the list.

7. Decision Modeling

A decision model is developed using QFD. QFD is a structured approach to defining stakeholder requirements and translating them into specific plans to produce products to meet them [2].

7.1 Decision Process

On a scale of 1-5, customers are asked to rate the importance of each of their requirements. This number is referred to as customer importance rating and is used in QFD in computing overall importance rating. Technical experts are then asked to generate technical descriptors; also called the "voice of the Engineer". These are the attributes of the grid that will enable it satisfy the stakeholders requirements.

7.2 Decision Computation

Improvement ratio is a ratio between our system's score as regards to needs satisfaction and our target value.

$$I = \frac{SS}{TV} \quad (1)$$

Where SS: System score, TV: Target Value.

Sales point which is an arbitrary value of either 1 or 2 is then allocated to each stakeholder need depending on how important the stakeholder rates that need

Absolute weight which is a value that shows how each need is satisfied by the technical attributes of the electrical grid is computed as

$$AW = I * IR * SP \quad (2)$$

Where AW: Absolute Weight, I: Importance

IR: Improvement Ratio, SP: Sales Point

Importance rating is a value that helps prioritize technical attributes in order of their importance.

$$\text{Importance Rating} = \sum_i^n (W_i * AW_i) \quad (3)$$

Where W_i: Correlation weight between the i^{th} stakeholder need and the i^{th} technical attribute.

RELATIONSHIPS		
Θ	Strong	5
O	Moderate	3
▲	Weak	1

Customer's Requirements \ Grid Upgrade Requirements	Transmission System Redundancy	New Generations	Clear Trees along Transmission Lines	Upgrade of conductor Sizes	Reduce Conductor Sagging	Replace old Transmission Line Equipments	System Automation	Decentralize Control Function	Tanzania	Uganda	Kenya	Target	Importance(Priority)	Improvement Ratio	Sales Point	Abs. Weight
									Competitive Evaluation							
Reduced blackouts	Θ	Θ	Θ	Θ	O	Θ	Θ	Θ	5	5	6	8	5	0.750	2	7.50
Stable Frequencies	▲	Θ	▲	O	O	Θ	O		6	7	5	7	4	0.714	1	2.86
Stable Voltages	▲	Θ	▲	O	O	Θ	Θ	O	5	6	7	7	4	1.000	1	4.00
Continuity in supply	Θ	O	▲	O	Θ	Θ	Θ	Θ	3	4	6	9	5	0.667	2	6.67
Cheap Power		O		▲	O	▲	▲		8	7	6	9	4	0.667	2	5.33
Clean Power		O		▲					5	5	8	5	3	1.600	1	4.80
Safe Power			O	▲	O	Θ	Θ	▲	5	3	9	8	4	1.125	1	4.50
Technical Dificulty	5	4	1	3	4	5	3	2								
Importance Rating	78	122	65	93	106	133	127	87								
Priority	7	3	8	5	4	1	2	6								

Figure 1: Quality function deployment

8. Discussion and Conclusion

From QFD's priority list, replacing old transmission lines equipment will have the most impact on grid reliability. Other grid upgrade requirements comes in the order as shown in figure 1.Faced with financial constraints, a country will implement these technical aspects in the order of priority and achieve desired reliability at an economical cost. The procedure has therefore demonstrated application of systems engineering incorporating QFD to grid upgrade problem.

REFERENCES

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