DISTRIBUTION NETWORK UPGRADING BASE ON EXPECTED UTILITY BY USING INSURANCE MODEL

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ABSTRACT

It is customer who defines quality and organizations have to consider quality in customer view point. Nowadays, the concept of quality no longer equals to standards compatibility but it is defined as equal to the need of customer. In power industry, it is important to provide customer with reliability and quality, the same has been provided a lot in power supply industry tradition and several procedures have been performed to improvement the reliability. Such improvements dictated a lot of costs for customer. Now it seems that it is essential more than ever before that customer must receive right to choose the reliability rate by himself or herself. This paper plans to represents a model of reliability consistent with desired reliability in views of the distribution company as well as the customer. Different levels of reliability are suggested to provide the customer demanded desired. According to the insurance model, the customer will receive compensation if the guaranteed service is not available.

INTRODUCTION

Not very long in the past, customer satisfaction was regarded as a one-dimensional construct. In other word, it seemed that the satisfaction of customer would be met more if more technical properties of merchandise are supplied. However, extensive meeting of any needs does not imply necessarily that customers are more satisfied but the type of need is crucial. Organizations must invest in the field that would result in more customer satisfaction.

The energy rate to be received from customer has two components: the cost of energy and the cost of quality delivering energy to the user. The quality depends to what different customers need. It is necessary that the power provider provides the levels of reliability the different customers demand. The rates that customers would be charged, depends to various services the power provider delivers to them. In this paper, Kano Model is used to identify the need of customer. Then, the customers' different levels of charge, how to determine the numbers of customers in each level in terms of the utilitarian reliability based on Kano Model are explored.

UTILITY THEORY

It is essential to explain the concept of utilitarian risk briefly. Figure 1 show that customers are classified in three categories based on their expected utilitarian service: risk averse and risk neutral, risk seeking [1].

- Risk Averse people**:** They are ready to pay higher than the exact value of risk to avoid it. They prefer to receive guarantee so they incline more to avoid the risk. Their behavior is in concave form.
- Risk Neutral people: They are ready to pay the exact value of risk to avoid it and they do not want to receive guarantee and are indifferent to risk. Their behavior is in linear form.
- Risk Seeking people: They show no inclination to receive guarantee and they believe that the exact value of risk is lower than the real damage. Their behavior is in convex form (Figure 1).

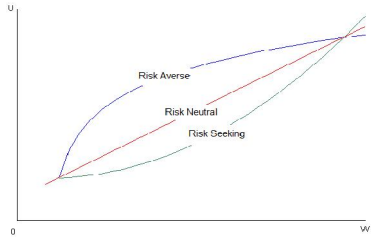

Figure -1 *Behavior Function of different people: U refers to utility and W refers to wealth (reliability).*

It is when the DIStribution COmpany (DISCO) does not expect profit from reliability improvement, the company would be indifference to reliability increase or the company will decide to increase the reliability only if it is measured cost effective. When the reliability is increased, the utility of the DISCO is decreased due to increase of cost related to higher reliability; this behavior is in linear form.

Reliability utility is regarded as the risk aversive in customer's view. It means that customers incline to pay higher than the probable damage to avoid the outage but it is noted that the reliability utility curve has a turning point for higher level customers. In other word, the customers don't like to pay extra money from value of utility higher than a limit. Reliability utility is different in view of different customers. Every customer chooses different rates of reliability utility based on his or her need and affordability. As it mentioned, DISCO has neutral utility toward reliability improvement, but it must be give a guarantee any disadvantage of DISCO. Whereas the navigate of customers is risk aversive if upgrading is performed based on their requests, it will supply enough incentive for company.

KANO MODEL

Kano Model is used in this paper to identify customer's needs. Two questionnaires (Functional and Dysfunctional) are given to customers to explore their needs as a model (table 1). The first questionnaire concerns with functional responses if the customer has the product of that

characteristic and the second one concern with dysfunctional responses if the customer does not have the product of that characteristic [2]. Then, Kano Model is combined with a question about the value of the customer's demand in order to make it more efficient.

These data must be transformed into quantitative data in order to be used in reliability presentation. Therefore, various weights are used for different answers (table 2) to transform qualitative answers into quantitative data.

Kano Model is used to give a model for the customer's need as well. The answer the customer would give to a question may imply the importance of the need for the customer. For example, customers would measure different values for their needs. It means that different customers may scale different money equivalence for the value of their need. Therefore in [3], in addition to functional and dysfunctional questions, customer is asked to give the value of his or her need in numerical count between 0-1(table 3).

To the nature of distribution network, there exist some financial and technical limitations in terms of one-customer service provision. Therefore, it is essential to identify the higher level needs of customers such as feeder.

The terms (x_{ij}, y_{ij}, w_{ij}) show the response of j^{th} customer in the i^{th} feeder to the non-functional, functional and the response to the question about the importance of the certain need for the customer, respectively. x_{ij} and y_{ij} mean "What are your feels?", w_{ij} means "How much do you estimate the value of your needs?".

TABLE 1- Kano Questionnaire

Question	Answer
Functional form of the question (*e.g., if the outage hours reduce, how do you feel*?)	□I like it that way □It must be that way □I am neutral □I can live with it that way □I dislike it that way
Dysfunctional form of the question (*e.g., if the outage hours do not reduce, how do you feel*?)	□I like it that way □It must be that way □I am neutral □I can live with it that way □I dislike it that way

TABLE 2- Kano Evaluation Table

Answer to the Kano question	Functional form of the question	Dysfunctional form of the question
I like it that way (like)	1	-0.5
It must be that way (must be)	0.5	-0.25
I am neutral (neutral)	0	0
I can live with it that way (live with)	-0.25	0.5
I dislike it that way (dislike)	-0.5	1

TABLE 3- Scores for Self-Stated Importance

Not important	Somewhat important	Important	Very important	Extremely important
0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

Now, we must estimate the average of the responses the customers of a feeder has given to a certain characteristic in order that the DISCO can determine on the characteristic.

$$\bar{X}_i = \frac{1}{J}\sum_{j=1}^{J} w_{ij}x_{ij}, \qquad \bar{Y}_i = \frac{1}{J}\sum_{j=1}^{J} w_{ij}y_{ij} \tag{1}$$

The plot $(\bar{X}_i, \bar{Y}_i)$ can be drawn in a two-dimensional diagram in order to different needs of customers are to be compared. The diagram can show the needs of customers in different fields such as attractive, one-dimensional, must-be, indifference, reverse and questionable(Figure 2).

The positive part in the above equation, which can be referred to as polar numbers, is very important for network upgrading. The characteristic of customer request can be represented as a vector $\vec{r}_i \equiv (r_i, \phi_i)$, where $r_i = |\vec{r}_i| = \sqrt{\bar{X}_i^2 + \bar{Y}_i^2}$ is the magnitude of $\vec{r}_i$ and $\phi_i = \tan^{-1}(\bar{Y}_i / \bar{X}_i)$ is the angle between $\vec{r}_i$ and the horizontal axis. The rationale of representing the satisfaction and dissatisfaction as a vector is that it becomes equivalent to a polar form, i.e., the magnitude of the vector denotes the overall importance of customer need and the angle ϕ_i determines the relative level of satisfaction and dissatisfaction.

Therefore, the magnitude of the vector (r_i) is called the importance index; and the angle (ϕ_i) is called the satisfaction index.

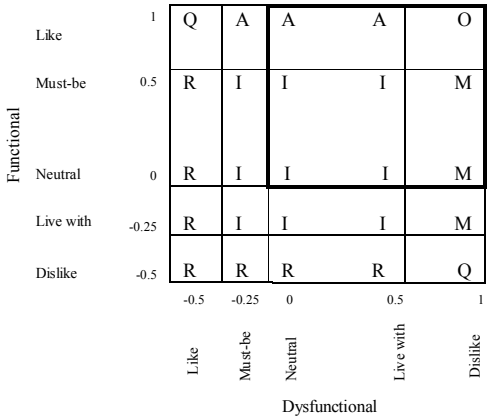

Figure 2- *Tow dimensional Kano model. (A, Attractive; O, One-dimensional; M, Must-be; I, Indifferent; R, Reverse; Q,Questionable.)*

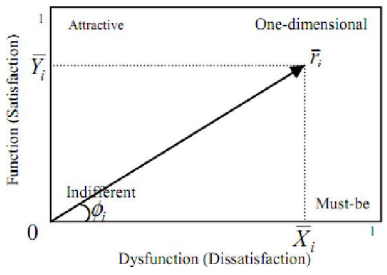

Figure 3 - *Vector representation of customer perception on a Kano model*

It is important to present customer upgrading's need briefly as follows:

- Must-be Needs: If these needs are not satisfied, customer would be unsatisfied severely. Customer assumes these needs as inevitable so, if realized, they would not result in customer's satisfaction. In fact, this level of service is considered as primary criterion and inevitably essential and if this level is accomplished, it would not result in customer's dissatisfaction only. If this level is not fulfilled, the delivered service would no longer seem attractive for customer.
- One-Dimensional Needs: Customer satisfaction depends on how much his or her needs are accomplished. It means that the satisfaction of customer is higher if his or her needs are more met and vice versa. It is clear that customer often demands his or her needs.
- Attractive Needs: These needs are neither expressed clearly nor they are expected to be realized by the customer and, if met, the customer would be pleasant extremely and, if not met, they would not lead to customer's dissatisfaction.
- Indifferent Needs: One category of characteristics of any product is not regarded as a qualitative need and does not relate to customer's satisfaction, if met or not met.

The equation $\rho_i = \frac{2\sqrt{2}}{3}(1-\frac{\phi_i}{\pi})r_i$ can be used to show the characteristics of a need with an index. This equation is intended to have both index of importance r_i and index of satisfaction ϕ_i and it can be used to compare the needs with each other. Up to this step the DISCO can identify different needs of customers and can compare them with each other. These numbers are used for representing desired reliability in view point of customers. First, the demanded reliability for each customer must be determined if it is to deliver service based on the desired service each customer demands.

INSURANCE MODEL

In [4-5] DISCO is able to give a desired service to customers by using insurance model. In this paper for more efficiency, it is proposed a new mechanism of the insurance. It is obviouse that any customer must be charged based on his/her service demand and if these services were not provided, their providing costs must be paid by DISCOs. the lowest and the highest levels of servicabilty are shown by R_{min} and R_{max} respectively, the demanded reliability is represented as Rc_i.

$$Rc_i = R_{\min} + (R_{\max} - R_{\min}) * \rho_i \quad (2)$$

Therefore, the insurance rate is defined as the function of customer's needs (r_i, ϕ_i) and the cost of service upgrade $C(Rc_i)$:

$$\Pr_i = K_1 * C(Rc_i) * \left(1 - 2b * \frac{\phi_i}{\pi}\right) * r_i \quad (3)$$

The insurance rate is related with indexes of importance and satisfaction by b and K_1. If the DISCO intends to charge customer for the insurance rate due to realized demand and related satisfation, it can relatively change b. The company is also required to pay compensation if it cannot deliver the desired service for customer:

$$\mathrm{Re}_i = K_2 * X_i * (Rc_i - R_i) \quad (4)$$

The rate of compensation is directly related to how customer feels if the demanded service would not be upgraded (X_i). The spicific states must be scrutinized in order to clear the relationship between insurance rate and compeation rate. Generally, the relation between insurance rate and compensation can be represented as follows:

$$\sum_i \Pr_i = \sum_j \mathrm{Re}\, j + \sum_l C(Rc_i) \quad (5)$$

Some of the most important special cases can be considered as:

1. If the upgrade is not fulfilled or the cost of upgrading is zero. In this case, we calculate the relation between K_1 and K_2, by substituting (3) and (4) in (5) as follows:

$$K_1/K_2 = \sum_i \cos(\phi_i) * (Rc_i - R_{\min}) \Big/ \sum_i (C(Rc_i) * (1 - 2b * \phi_i/\pi)) \quad (6)$$

2. As another special case let the customers only wanted to be compensated all customers by DISCO of their service have been curtailed. Under this condition for all customers (ϕ_i=0), and therefor we have:

$$\Pr_i = K_2 * \left(\sum_j Rc_j \Big/ \sum_j (C(Rc_i))\right) * C(Rc_i) \quad (7)$$

Therefore, insurance rate is related only with the cost of upgrade.

3. Now, it is assumed that customers are not dissatisfied with not receiving their demanded service(ϕ_i=π/2):

$$\mathrm{Re}_i = 0 \ and \ K_1 = 0 \quad \Rightarrow \Pr_i = 0 \quad (8)$$

Therefore, insurance rate is also zero. It is because, the assumed risk for the company is indifferent risk and so, the company tries to invest in order to avoid loss. In this state, because no customer has demanded any compensation, the DISCO would not want to improvement the reliability. It is noted that the above assumption is intended only for parameters identification. In practice, the number of customers will be increased if customer demanded services are delivered properly and the intended profit would be realized for the company, resulting in enough motivation for the company to improvement the reliability rate.

4. As the final case, we assume that the optimal satisfaction index is realized if each customer receives the exact demanded reliability. Hence:

$$\sum_i K_1 * C(Rc_i) * (1 - 2b * \phi_i/\pi) * r_i = \sum_l C(Rc_l) \quad (9)$$

By solving this and equation (6), one can calculate two parameters based on the third and then, optimization is solved in order to determine the level of service.

The different reliabilities are regarded to have various

utilities from the views of the DISCO and its customers. We intend to suggest an optimum point based on DISCO expected utility along with the demanded utility in view point of different customers to remove drawbacks from the previous methods. The goal is to maximize the customers' utility and not disadvantage of DISCO.

$$\max \sum_{i=1} \rho_i * R_i$$
$$st:$$
$$\sum_i \Pr_i - \sum_i \mathrm{Re}_i - \sum_i C(R_i) \geq 0 \qquad (10)$$
$$\mathrm{Re}_i = K_2 * U(Rc_i - R_i) * X_i * (Rc_i - R_i)$$
$$\Pr_i = K_1 * C(Rc_i) * \left(1 - 2b * \phi_i / \pi\right) * r_i$$

CASE STUDY

In this paper for analyzing proposed model, a questionnaire is schemed based on Kano model and it is given to customers, randomly. Their answers are averaged for every feeder. The parameters of Kano model, demanded services and the cost of upgrade are shown in table 4. This paper assumed that the cost of upgrade is a Quadratic function with respect to delivered reliability. The magnitudes of K_1 and K_2 are obtained from b and the value of K_1 is increased if the b is increased, but the variation of K_2 is fixed.
An optimization based on genetic algorithm is performed for determining the level of delivered services and compensations to customers in the different values of b.

TABLE 4- The Needs of Customers and Their Costs

Feeder	r_i	ϕ_i	Rc_i	$C(Rc_i)$
1	0.61	36	99.43	22.96
2	0.72	25	99.52	34.16
3	0.85	24	99.62	48.23
4	0.71	18	99.54	36.29
5	0.39	11	99.10	11.91
6	0.45	37	99.30	11.37
7	0.53	7	99.43	22.92
8	0.52	20	99.39	18.99
9	0.80	37	99.54	35.91
10	0.65	21	99.49	30.21

TABLE 5- Optimized Service Level, Reimbursement and Premium by Different b

Feeder	$b=0$			$b=1$		
	$\Pr_i$	Re_i	R_i	$\Pr_i$	Re_i	R_i
1	20.5	0	99.4300	16.97	0	99.431
2	36.1	0	99.5287	35.90	0	99.528
3	60.2	0	99.6313	60.77	0	99.626
4	37.8	0. 51	99.5404	41.68	1.10	99.537
5	6.83	0	99.2798	8.250	0	99.284
6	7.51	0	99.3034	6.08	0	99.305
7	18.0	0	99.4374	22.80	0	99.436
8	14.5	0	99.3968	15.52	0	99.397
9	42.2	0	99.5431	34.16	0	99.541
10	29.3	0. 81	99.4928	30.90	0	99.498

As shown in table 5, whereas the objective function is the maximization of the customer satisfaction, in some cases the value of delivered reliability is more than requested value otherwise the customers receive compensation. Delivered service will change with variation of parameters. For example in feeder 1, if the value of b change from zero till one, notwithstanding the increase of delivered service, the magnitude of insurance rate has sizable decrease. The needs of customers are modeled as two-dimensional. With change of the factors of satisfaction and importance by changing b and k_1 will change the value of the insurance rate and compensation. This optimization gives a suitable view about how deliver of service based on request and utility of DISCO and customers.

CONCLUSION

The current methods of delivered services to customers are inefficient because they didn't consider to the needs of them. This paper from customers and DISCO point of view about reliability improvement proposed an insurance mechanism based on Kano model. Whereas various services have different costs, this paper an insurance structure was proposed in which the customer payment is proportional to their desired level of services. The main attribute of this method is two dimensional modeling where the optimization of customer requests and the costs of reliability improvement, both are possible.

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