EFFECTIVE DESIGN OF THE REWARD-PENALTY SCHEMES TO REACH THE HIGHEST PERSUASIVENESS IN SELECTING INVESTMENT STRATEGIES BY ELECTRIC DISTRIBUTION UTILITIES

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ABSTRACT

This paper aims to propose a new approach in designing Reward-Penalty Schemes (RPS), which so far have been used as the preferred tool in Service Quality Regulation (SQR). For the purpose of explaining the method, various types of RPS are divided into three categories. The concepts of these RPS categories, used in this paper, are inspired by intrinsic behavior of organisms as will be described in detail.

INTRODUCTION

Despite the fact that failures in distribution systems constitute a high percentage of customer’s interruptions, they have received less attention than generation and transmission systems at least in the amount of academic and industrial publications in the past decades. The main reason that makes this high percentage of contribution in customer’s interruption is its widespread covering of all the civilized places. Moreover, the huge numbers of distribution system components considerably contribute to higher failure rates. In addition, distribution systems have an inherent monopoly structure that if not properly regulated, can cause serious damages to the customers.

Two main ways that regulators can have a control over the Electric Distribution Utilities (EDUs) exist through regulations, i.e., cost-based and performance-based regulation. In cost-based regulation, prices are set to cover the costs of the firm. Under this form of regulation, there is a little incentive for cost efficiency and hence, is the main drawback of this regulation. However, a more competitive type of regulation, known as performance based regulation (PBR), has recently been used as the regulation policy in some countries. Under PBR, a regulator uses price or revenue caps to motivate the EDU for cost efficiency. The incentive for cutting the cost causes a decrease in the investment and operational cost and an increase in the maintenance interval. In this condition, the quality of service has been deteriorated. Therefore, Service Quality Regulation (SQR) must be defined to support them. In this type of regulation, penalties and possible rewards are controlling the company’s decisions.

For the EDUs, profit-making is the most important concern and plays the most important role in their decisions. So, in applying the SQR to the system, the effect of newcomer factors like rewards and penalties must be assessed. Considering the regulations, the utility should conduct an investigation in examining different strategies.

SERVICE QUALITY REGULATION

The term SQR is a general word for PBR concerning regulations which encourage firms to enhance their performance. This performance may include improvement in system reliability, power quality or customer services, and so on. Improvement in system reliability is equal to continuity of supply which concerns a single service, “supply of electricity to the customers” or in the other form, absence of interruption. There are different types of SQR; however, due to their straightforward practical application, RPS schemes are of the most interest from both regulators and regulated utilities perspectives.

The reason that makes RPS the most useful tool in SQR is because it ensures the regulator about the average performance of the system. To measure this average performance, one or two system level reliability indices are usually selected. The regulators use these indices as a reference point in their regulation. They measure and compare the reliability of the regulated distribution system with these desired reference values.

After selecting the desired index or indices to be regulated, the next step is to choose a point as performance standard (PS) which is shown in Figure 1, as a benchmark. Although the quantity of this PS is absolutely depends on the regulator and regulated utility historic performance, its value commonly equals to the mean value of regulated index of the system. Companies with performance better than PS are generally rewarded and companies with worse quality are fined; however, as shown in Figure 1, there is an area in some of the regulation policies which EDUs neither be fined nor be rewarded. This is referred to as the dead zone. Also, some regulatory policies opt for capping the rewards and penalties to a predefined level. Consequently, there are three types of RPS in use, linear, capped, and capped with a dead zone.

The focus of this paper is on the cap values of the RPS. Therefore the approach presented in this paper is suitable
for capped and capped with a dead zone types of RPS and it is not applicable for the linear one.

To briefly describe the main points of RPS, its main parameters are introduced in the following. As is illustrated in Figure 1, there can be a dead zone area around the PS. The right boundary of this area is called the reward point and the left boundary is called the penalty point. The companies with better or worse performance of these points will be rewarded and penalized, respectively. If the reliability is worse than the right boundary of the dead zone, the company will be penalized. The penalty value increases as the index gets further from PS and will be capped at the Maximum Penalty Level (MPL). It is the same for the reward zone. If the value of the index is better than the left boundary of the dead zone, the company will be rewarded and as the reliability improves the reward value increase as well, till the point that it will be capped at Maximum Reward Level (MRL). The RPS is conducted based on the regulator’s goal and condition of the regulated network and may be annually changed or be fixed for longer periods.

![Figure 1. Linear, capped and capped with a dead zone RPS.](image)

The focus of this paper is on the cap values, i.e., MRL and MPL. To describe the main thesis of this paper, the philosophy of rewards and penalties in intrinsic behavior of organisms is first illustrated in the next section.

**THE CARROT AND THE STICK APPROACH**

The carrot and stick approach refers to a procedure of offering a compound of rewards and penalties to induce a behavior. It is named in reference to a cart driver dangling a carrot in front of a mule and holding a stick behind it as shown in Figure 2. The mule would defiantly move towards the carrot because it wants the reward of food, while also moving away from the stick behind, since it does not want the punishment of pain, thus drawing the cart [1]. The speed of this moving can be different based on the amount of carrots and the severity of the pain of the stick. At this point, selecting the suitable amount of carrots and sticks plays an important role to reach to the best performance.

![Figure 2. The Carrot and the stick.](image)

The design of this compound is strictly differ from case to case. For some cases, there should be higher amount of penalties comparing to the rewards and vice versa. Another noteworthy is that punishments and rewards have different impacts on different organisms. Among human beings, for instance, on one hand, punishment can have destructive impact on a given type of people, while reward can have a great impact on the same type of people.

This concept of the carrot and the stick approach is used in this paper to design the RPS more effectively for the distribution systems. In the other words, selecting the amount of carrots and the intensity of stick for different EDUs is proposed in this paper.

**SUGGESTED APPROACH IN DESIGNING REWARD-PENALTY SCHEMES**

In the RPS, “rewards” and “penalties” are in use as the two monetary persuasive tools for distribution utilities to invest in their system. The term “Service Quality” is focused on the continuity of supply in this paper. To persuade distribution companies more effectively to show a better performance, which is the aim of this paper, the regulator should consider the statistics of the network under regulation. Based on these statistics and the approach presented here, the regulator can decide to select the MRL and MPL more effectively.

In this paper, distribution systems are divided into three different categories, and for each category, designing the effective RPS is described. As will be addressed, some networks are persuaded more effectively by rewards (called Reward-Biased in this paper), while some by punishment (Penalty-Biased), and some reacts equally to both rewards and penalties which are called Without Bias. These RPSs are respectively shown by red, blue and black lines in Figure 3.

![Figure 3. Suggested approach in designing reward-penalty schemes.](image)

Commonly, the cap values of reward and penalties are the same. But as it will be shown, for the distribution systems with recognizably good reliability performance and on the other side, for the systems poorly functioning, these cap values should be different from each other. Higher reward cap means higher incentives for the former
while higher penalty cap means higher incentives for the later.

![Figure 3. Configuration of three different RPS models.]

**CASE STUDY**

In this case study, SRRTS presented in [2] is used for the analysis. System Average Interruption Duration Index (SAIDI) [3] is employed as a system reliability index for the sake of comparison between the cases. Performance Standard was selected 10 times more than the system real SAIDI presented in [2]. In other words, it was conceived that a system with this SAIDI level does not need any bias in its RPS.

As suggested in [4], the cap value of reward and penalties should be selected as a percentile of the system Total Annual Revenue (TAR) which is calculated in [5]. In this regard, 2, 4 and 6 percentile of TAR is selected as different caps of rewards and penalties. The blue RPS in Figure 3 is called penalty biased RPS. It means that the cap value of penalty far exceeds the cap value of the reward. In this paper, the cap value of the reward and penalty for this type of RPS is selected 6 and 2 percentiles of the system TAR, respectively. In contrast with this type of regulation, reward biased regulation which is shown by the red line in Figure 3, uses the 6 percent of TAR for the reward and 2 percent of it for the penalties. And finally, the RPS that uses the same capes for reward and penalties is described by the black lines in Figure 3. It should be noted that the average of the reward biased and penalty biased caps is the same as the cap value in the type with no bias. However, the main focus of this paper is on the comparison between the reward biased and the penalty biased types to select the meaningful amount of carrots and sticks for the EDUs and these caps can be selected in different manners.

To put an example to the presented approach, the system with the SAIDI value of 0.23 is considered as a system that needs reward to be persuaded more. In the opposite side, the system with SAIDI value of 23 hours per year is considered as a system that must be penalized more severely. Note that based on the data presented in [5], and by selecting the PS equal to 2.3 hours per year, both SAIDI values of 0.23 and 23 hours are located in the caped zone of Figure 3. Also note that the numerical example presented here is just to present the use of the carrot and the stick theory in designing the distribution system SQR in the form of RPS, and so, it is not a conclusive example. Many other parameters deals with selecting the details of an RPS structure that are all presented in [4], in detail.

A summary of RPSs applied to the system is presented in Table 1. The blue parts are related to the penalty biased, the red parts are in accordance with the reward biased and the black parts are associated with the without bias illustration of Figure 3.

As can be seen, in the system attributed poor reliability characteristics of 23-hour average annual interruption duration, as the cap value of penalty increases, the punishment increases as well. This provides the harsher sticks for the EDUs. On the opposite side, by increasing the reward cap, the EDUs incentives in their future investment increase as well. Noteworthy is that it does not occur in an opposite manner.

<table>
<thead>
<tr>
<th>SAIDI(hr/year)</th>
<th>Reward Cap</th>
<th>Penalty Cap</th>
<th>Penalty-Reward</th>
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</thead>
<tbody>
<tr>
<td>23</td>
<td>0.6×TAR</td>
<td>0.2×TAR</td>
<td>+130 k$</td>
</tr>
<tr>
<td></td>
<td>0.4×TAR</td>
<td>0.2×TAR</td>
<td>+260 k$</td>
</tr>
<tr>
<td></td>
<td>0.2×TAR</td>
<td>0.6×TAR</td>
<td>+390 k$</td>
</tr>
<tr>
<td>2.3</td>
<td>0.4×TAR</td>
<td>0.4×TAR</td>
<td>0</td>
</tr>
<tr>
<td>0.23</td>
<td>0.2×TAR</td>
<td>0.6×TAR</td>
<td>-130 k$</td>
</tr>
<tr>
<td></td>
<td>0.4×TAR</td>
<td>0.4×TAR</td>
<td>-260 k$</td>
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<td></td>
<td>0.6×TAR</td>
<td>0.2×TAR</td>
<td>-390 k$</td>
</tr>
</tbody>
</table>

Table 1: Reward and penalty estimation based on the system statistics.

**CONCLUSION**

There is a fact that in the monopoly structure of distribution systems, regulating the behavior of EDUs plays a very important role to prevent them from financial abuses. In this paper, a method for persuading the EDUs more effectively in their investment on distribution system was suggested. The author’s opinion on the way toward designing an RPS for different types of distribution systems are offered and proved by some examples. At last, it was concluded that different regulatory schemes have to be adapted for different utilities with different reliability performances and so, this leads to various amounts of rewards and penalties for the utilities.

**REFERENCES**

University of Oregon Economics Department.


