PRINCIPAL REQUIREMENTS OF DESIGNING THE REWARD-PENALTY SCHEMES FOR RELIABILITY IMPROVEMENT IN DISTRIBUTION SYSTEMS

Hossein MOHAMMADNEZHAD-SHOURKAEI
Center of Excellence in Power System Control & Management
Department of Electrical Engineering,
Sharif University of Technology –Tehran, Iran
H_m_shourkaei@ee.sharif.edu

Mahmoud FOTUHI-FIRUZABAD
Center of Excellence in Power System Control & Management
Department of Electrical Engineering
Sharif University of Technology –Tehran, Iran
Fotuhi@sharif.edu

ABSTRACT

An important consequence of restructuring in the power industry is the emergence of service quality regulation in the distribution network. Reward/Penalty Scheme (RPS) is regulated to assure the service reliability. RPS is a financial tool designed by regulator to prevent the service reliability deterioration. RPS rewards the utility who is providing good reliability and penalizes the utility who is providing poor reliability. This paper investigates the main requirements for designing and implementing of an effective RPS. It describes that the conditions of country that implements the RPS such as ownership of distribution utilities (i.e. private or public), regulation of tariff setting, subsidizing the electricity, regulatory policy, and other factors force the regulator to set a unique scheme for reward and penalty. The aim of this paper is to comprehensively describe the different types of RPS based on the mentioned factors.

INTRODUCTION

The electricity distribution is categorized as monopoly industries. The monopoly environment induced the distribution system operators (DSOs) to increase the electricity tariff and decrease the service quality to gain more profits. For eliminating the undesirable effects, the regulators have used the rate of return (ROR) and cost of service (COS) regulations to set electricity price [1]. In this paradigm, the tariff is set based on the utility cost such that it covers all operation, maintenance and capital costs considering a profit margin. As the cost reduction results in decreasing the price and consequently decreasing the profit, there was not enough incentive for DSOs to minimize the cost. The Performance Based Regulation (PBR) or incentive regulation has been replaced ROR/COS to encourage the efficiency [2].

The PBR was emerged by price control regulations such as price cap and revenue cap. In spite of traditional regulations, PBR motivates DSOs for cost efficiency to increase their profit. For example, in the UK the customer per employee ratio increased from 309 in 1990/1991 to 681 in 1999/2000 [1]. This was the good outcome of price control regulation. However, the cost cutting was the unfavorable effect of cost efficiency. Under price cap regulation, DSOs induce to defer the capital investment and maintenance activities to maximize profit. The cost cutting results in deterioration of the service reliability and increasing the customer's dissatisfaction [3].

For compensating this deficiency, the service quality regulation has been introduced to control the service quality and reliability in the presence of price control mechanisms [2, 4]. Typically, the service quality regulation covers the technical and non-technical aspects of activities in the electricity distribution and retail [4,5]. The concern about the commercial quality such as provision of a new connection and accuracy of metering is categorized as non-technical aspect of quality regulation. The continuity of supply and voltage quality are categorized as a technical aspect of service quality regulation [4]. Regulating the continuity of supply is more common than others and regulators have introduced some instruments to assure the desire level of reliability. RPS is a widespread instrument. Providing a relationship between revenue and service reliability level was the principal goal of the RPS to prevent reliability deterioration. The RPS as a financial tool determines service reliability benchmarks and sets rewards and penalties for exceeding or failing to achieve these benchmarks, respectively [6].

This paper investigates the main requirements for designing and implementing an effective RPS. Based on the regulatory goals, the ownership of distribution companies (i.e. private or public), the tariff setting regulation, and etc., different schemes for reward-penalty are introduced. The designing parameters such as measured indices, the effective factors in the calculation of indices, the amount of reward and penalty, the structure of reward-penalty are present. At the end, implementing considerations such as possible conflict between the managers and shareholder interests, error in the measurement, procedure of events recording, optimum time of performing reward/penalty mechanism, and the effective period of reward-penalty regulation will be discussed.

This study can help the regulators, specifically for regulators who want to initiate the service quality regulation, to design the RPS according to their political and technical conditions.

REWARD/PENALTY SCHEME

Reward and penalty are financial tools that motivate better performance. In this mechanism, a benchmark for reliability indices is pre-defined by regulator and if DSO hits to the benchmark, there is neither penalty nor reward. If it acts better than the benchmark, he is rewarded. Otherwise he is penalized. A general form of RPS has a dead zone as shown in Fig. 1.

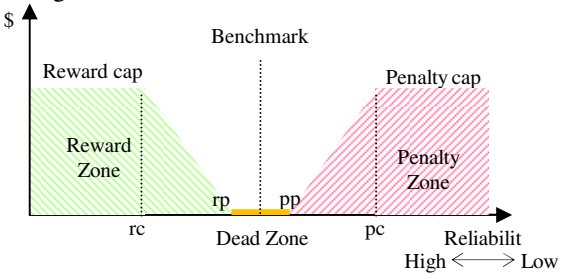

Figure 1. General structure of reward-penalty mechanism

Dead zone is a zone without penalty and reward. If reliability index is worse than the right boundary of the dead zone, a penalty is assessed. The penalty is increased as reliability degrades and is capped at the penalty cap. The reward zone works like the penalty zone. If reliability index is better than the left boundary of the dead zone, reward is initiated. If reliability index improves, the reward grows and is capped at the reward cap [6, 7].

REQUIREMENTS FOR DESIGNING RPS

Measured indices

There are probably large number of indices that could be used to measure the DSO service reliability. This approach may ensure that all service reliability aspects are in a customers' favorite level. However, managing and collecting data for calculating many numbers of indices are very time and money consuming for DOS. In addition, the data verifying and the setting relationship between the indices and RPS are very complicated for regulator.

On the other hand, providing a few specific indices can facilitate the implementing of RPS. The few indices can easily be managed by the DSO [9]. Usually, one or two indices are common to be regulated. For selecting the indices some consideration should be taken account:

- The selected indices should be quantifiable.
- The selected indices should be independent than others.
- Selecting the indices is extremely depending on the type of customers in the DSO territory. For example, in a DSO with high density of industrial customers, the using of indices that represent the momentary interruption accompanied with other indices can more reflect the customers' concern.
- Sufficient data should be available to calculate indices.
- For initializing the RPS, the available instruments for measuring and recording of indices should be considered.

Usually the system based indices such as System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI) and Energy Not Supplied (ENS) are the most popular indices used in RPS [6]. For the regulators who want to initiate the RPS, applying one index may be enough to motivate the DSO for better performance. However, it should be noted that the customers concern about all indices are not identical. For example, the customers located in the rural area may resign the frequent outages but concern about the duration of outage [9]. On the other hand, some industrial customers may be very concern about the frequent outages since after each interruption; they have to turn on their factory with expensive start up costs and could possibly lose the production in process. Therefore, the selection of two or more indices can satisfy all customers' concern. For the case of using multi-indices, the weighting of each index based on the customers types is a good approach that correctly reflects the customers' concern [8]. For example, in the rural area, the weight of SAIFI should be less than that of SAIDI from the RPS point of view.

Effective factors in the calculation of indices

The identifying the interruption causes is the essential step in calculation of reliability indices. There is a wide range of phenomena that make an interruption. However, interruptions can occur based on two factors:

External factors:

Managing of these factors is out of DSO control and it cannot reduce the duration and frequency of these outages in short term. The outages due to generation and transmission failures can be categorized in this group. The word "short term" was used intentionally, because in mid and long term, the DSO can reduce the impact of upstream events by installing distributed generation. The outages due to external events should not be considered in calculating the indices.

Internal factors:

The outages due to factors such as failure on distribution equipments, human failures, maintenance of equipments and adverse weather condition can be managed by DSO. In some countries, the outage due to maintenance activities is not considered in the process of indices calculation. They believe that the maintenance actions are essential work for improvement of reliability, while those may reduce the reliability in short term but improve it in long term. However, in other countries such as U.K, it is taken into account to force the DSO to perform the maintenance actions in a shorter time and reduce the outage durations. As the different damages due to planned and unplanned outages, it is better to separately calculate indices for both type of outages. Also in the case of weather condition, there are different approaches, some countries consider it for calculating indices but others ignore it. In the first glance, it should be seemed that the outages due to adverse weather conditions are outside of DSO control. While occurrence of these outages is unavoidable, the system restoration time is extremely dependent on the DSO crisis management for force major events. The consideration of outages due to adverse weather, forces the utility to set a clear plan for critical conditions. It should be noted that in the calculation of SAIFI, the outages due to adverse weather conditions must not be taken into account. But, in the calculation of SAIDI, they should be considered.

Benchmark setting

The next step is to determine a benchmark for each index. Benchmark indicates the start point of reward or penalty. If the utility performance is better than the benchmark, the utility will be rewarded and if it is worse than the benchmark, the utility will be penalized. Benchmark should be set such that the currently electricity tariff covers the cost of achieving to it [4]. However, in the real world, the calculation of exact cost of providing a level of service reliability is a multi dimensional and dependent problem. Therefore, regulators use other ways to define the benchmark as below:

Based on historical performance:
This way is used in some states in the U.S such as Massachusetts, Oregon, and New York. The benchmark for each index is set based on the rolling average performance of recent years, usually based on average of the last three years [8]. The goal of this approach is to motivate the DSO to maintain the current performance level. This may be effective if current level satisfies customers and rate of complaints is low.

Based on targeted value:
Countries such as Italy and Hungary set a benchmark based on the initial value of index accompanied with an annual improvement [4]. In this approach, the regulator believes that the level of service reliability is not satisfactory for customers and tries to motivate the DSO using annually increasing the benchmark. The value of annual improvement is dependent on the initial value, if the initial value is good, the smaller improvement is expected and if the initial value is poor, the larger improvement is considered.

Based on Competition:
This approach is based on yardstick theory such that the reliability provided by DSOs in one cluster is compared with that of other DSOs located in the same cluster. The DSOs are clustered based on factors associated with their environmental, geographical and network conditions. The benchmark is set based on average performance of DSOs placed in one cluster. The benchmark value is calculated at the end of each period and applies for the same period.

The relationship between revenue and performance

The most important step in designing the RPS is to determine the relationship between revenue and performance. Without setting such relationship, there is not any guaranty that DSO be responsible for deterioration of network reliability. For these reasons, the regulator defines a penalty and reward that can be applied in different ways:

DSO tariff control:
In this approach, the electricity tariff varies in each DSO based on this performance. If the reliability index is exceeded the benchmark, DSO should be penalized and the electricity tariff in the same DSO is decreased. Otherwise, if the index is less than the benchmark, DSO should be rewarded and the tariff in the same DSO is increased. The value of change in the tariff is based on the incentive rate that represents the monetary worth of per unit change in reliability. For example, for SAIDI, the incentive rate is calculated by multiplying the annual average load (in kw) by the value of energy not supplied [€/(minute kW)]. This approach is currently used in Hungary [4].

Country tariff control:
In some countries such as Italy, the identical tariff for all DOSs must be applied. For this reason, an equalization fund is used that penalties received from poor performed DSO are deposited in this fund and rewards are taken from the fund. At the end of year, when the fund is negative, it illustrates that the system reliability is improved more than the pre-defined level and the tariff should be increased in all DSOs, when the fund is positive, it shows that the system reliability is deteriorated and all consumers pay a reduced tariff [4].

Direct penalty and reward:
In this mechanism, a fund is established. The good performing DSOs receive direct monetary reward from fund and poor performing DSOs deposit direct monetary penalty to the fund. In this approach, the tariffs are fix and customers are not affected by performance [8]. This approach can be useful for countries that the tariff setting is extremely dependent on political not technical issues.

Direct penalty and reward with summation zero:
In the previous mechanism, regulator may need money to reward good performed DSOs. this may face regulator with lack of budget. On the other hand, regulator may receive a large amount of money from poor performing DSOs. This may raise the DSOs doubt that regulators apply RPS for money making. For solving this problem, the regulator can establish a balance between reward and penalty such that the net difference turns to zero in a specified period [8].

Allocated Budget Control:
In some countries such as Iran, the DSOs are government-owned companies. For these, a specified budget is set by TAVANIR (the holding company in electricity generation, transmission and distribution). In this approach, a portion of DSOs budget can directly be tied to service reliability.

Directorate Bonus Control:
In the government-owned DSOs, the control of budget may not change the managerial behavior. While the substitution of directorate for undesirable performance is a common way, the control of directorate bonus can be an effective financial tool to motive them for performing good. If the service reliability is improved, the directorate bonus is increased and vice versa.

Reward and penalty structure

Different structures for reward and penalty can be introduced. The common forms of them are shown in Fig. 2 [5].

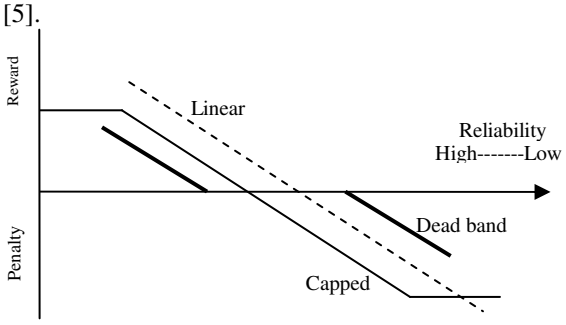

Figure 2. Different structures of reward and penalty

Linear RPS:
In this model, there is a linear relationship between reliability and reward/penalty. For each level of reliability, a reward or penalty can be determined such that it is proportion with the gap between the actual level and benchmark. The larger gap causes the higher reward or penalty.

RPS with dead band:
In some structures, the dead band is inserted. The reliability variation in this band is excluded from the reward and penalty. Indeed, this band is introduced to show that the small change in reliability cannot occur due to structural measures, but simply a stochastic change.

Capped RPS:
A cap is set to protect the customers and DSO from unfavorable effects of improperly designing the RPS. While there are not perfect information about the customer valuation in reliability point of view, for reduction of risk of high rewarding, a cap for reward is introduced. The penalty cap is defined for removing unbearable financial losses for DSO.

IMPLEMENTATION CONSIDERATIONS

Delay

After passing the RPS by regulator, a DSO needs time to be prepared for response to the RPS. When the RPS is passed, there are time steps to be done by DSO:

- The top managers study the RPS and map the company policy for response to the RPS.
- The middle managers get the policy to design alternatives and present them to the top managers. The best alternative is selected according to the budget and other operational constraints.
- The selected alternative is converted to the operation plan.
- The operating team executes the plan in a scheduled time.

The summation of these time steps may be larger than one year. Therefore, this time lag should be considered by regulators. It is proposed that evaluating of DSO is performed one or more years after passing the RPS.

Education

The education is another main subject in RPS implementation. After passing the RPS, the regulator should provide education materials and seminars to improve the knowledge of DSO about RPS. This helps the regulator to prevent probable objections of DSO about the scheme.

Conflict between the manager and shareholder

Usually in the DSO, the ownership and control & operation are separated. The shareholders select the top managers and they manage the utility. In this situation, the managerial interests are not likely aligned with the shareholders objective (i.e. profit maximization in private utility). Since in the private utilities, the salary of managers depends on the profit of utilities, they try to increase the profit of utility in the period of their responsibility. So, they may defer the capital investment and perform the maintenance of equipments in a larger interval. Deferring these projects may not extremely affect on the reliability in the short term, but may decrease the reliability in the long period. So, the managers increase the profit in the short term by cost cutting to increase their bonus. This behavior of managers may face the utility with a large penalty due to reliability deterioration in the long term. The appointment of managers for a larger period may decrease the undesired managerial behavior.

RPS effective period

As investments need a stable environment, the regulations should be fixed for a long period. The change of regulations in a short period faces the DSO with a great risk. For reduction the risk of DSO due to regulatory decisions, the effective period of RPS should be long. This period for Scandinavian countries and UK is considered to be five years [5].

Measurement error

The world experience about implementing of quality regulation shows that the data submitted by DSOs is almost involved error [1]. This error may be arisen intentionally or due to inaccuracy in metering device. The intentionally error can be omitted by establishing a framework for recording, reporting, and monitoring as well as considering an independent auditor. The installation of metering device with higher accuracy can reduce the device based error.

CONCLUSION

The application of service quality regulation is going to spread throughout to motivate the utilities to enhance their performance. The reward/penalty scheme is one of the world wide instruments that has been used by regulators to punish the utility that its quality is lower than the benchmark and reward the utility with performance higher than the benchmark. For designing RPS, principal aspects should be considered and this paper has comprehensively described them. Since different regulation structures have been established in different countries, the different mechanisms for reward and penalty has been presented. Also, this paper illustrated that there are some practical considerations that regulators should think about them in designing of RPS.

REFERENCES

[1] T. Jamasb and M. Pollitt, 2007 "Incentive regulation of electricity distribution networks: Lessons of experience from Britain", *Energy Policy*, vol. 35, 6163-6187.

[2] P. Joskow, 2006, "Incentive Regulation in Theory and Practice: Electricity Distribution and Transmission Networks", Working paper in economics, MIT, USA.

[3] A. M. Spence, 1975, "Monopoly, Quality, and Regulation", Bell Journal of Economics, vol. 6, 417-429.

[4] E. Fumagalli, L. Lo Schiavo, and F. Delestre, 2007, Service quality regulation in electricity distribution and retail, 1st edn Springer.

[5] V. S. Ajodhia, 2006, Regulating beyond price, integrated price-quality regulation for electricity distribution networks, PhD thesis, Delft University of Technology.

[6] R. Billinton, L. Cui, and Z. Pan, 2002, "Quantitative reliability consideration in the determination of performance-based rates and customer service disruption payment", IET Gen., Trans., and Dist., vol. 149, 640-644.

[7] R.E. Brown and J. Burke, 2000, "Managing the risk of performance based rates", IEEE Trans. on Power System, vol. 15, 893- 898.

[8] H. M. Shourkaei and M. Fotuhi, 2010, "Impact of Penalty-Reward Mechanism on the Performance of Electric Distribution Systems and Regulator Budget," IET Gen.,Trans., and Dist, vol. 4, 770-779.

[9] Synapse Energy Economics, Inc., 1997, "Performance-Based Regulation in a Restructured Electric Industry", *Report prepared for National Association of Regulatory Utility Commissioners*.