

DESIGNING A COMPREHENSIVE SEPARATED REGULATION MECHANISM OF DISTRIBUTION COMPANIES CONSIDERING SHORT AND LONG TERM ASSET MANAGEMENT

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ABSTRACT

The regulation of DSO is changing from the traditional approach to performance based regulation (PBR). In this paper a novel PBR approach is proposed for the regulation of a Distribution Company with consideration for asset management time scopes. In this regard a comprehensive separated regulation mechanism is presented so that the total expenditure for asset management is separated into two, capital expenditure (Capex) and operational expenditure (Opex). The separate Capex and Opex regulation is proposed for electric distribution company regulation. A new reward and penalty scheme is proposed to efficiently regulate the quality of the network at a desirable level. The proposed methods are applied on the Iranian electricity distribution company.

INTRODUCTION

Historically, DSOs have been regulated by two regulation methods namely ‘cost of service’ and ‘rate of return’. Under these methods the profit of DSOs was somehow dependent on their costs, they had very little incentive to improve their efficiency [1-3]. To provide an incentive for DSOs, performance-based regulations (PBR) are introduced to motivate the DSOs to improve their efficiency and to decrease costs [4]. PBR is a tool in the regulatory scheme for providing incentives for a regulated operator to behave in such a way that public interest is promoted.

Although the proposed regulations motivate the DSOs to increase their efficiency and to cut costs, they also lack incentives for service quality and reliability [5]. Because of the inherent weaknesses in the PBR, regulators employ various forms of RPS to ensure reliability. RPS induces the DSOs to provide reliable services through penalizing poor performance and rewarding good performance [6].

A typical form of the penalty/reward scheme is shown in Fig.1. As shown, the general form of RPS contains three zones: reward, dead and penalty zones. The dead area is where neither a penalty nor a reward is assessed. The penalty and reward areas are where the performance of DSO is in good and levels respectively.

The reason for using a dead zone is to dampen unintended

penalties and rewards owing to stochastic variations in quality. The penalty and reward areas are where the performance of a DSO is at good and poor levels, respectively. As the reliability of service is worsened or improved the penalties or rewards increase—respectively, and are capped where a certain value is reached [6, 7]. The reliability indices utilized in RPS work is based on system average measures of interruption, such as system average interruption duration index (SAIDI) and system average interruption frequency index (SAIFI) [8]. SAIDI is used in this paper as the reliability index.

Utilising a reliability index in RPS is proposed in [9-12]. In [13] an algorithm is presented to obtain the parameters of RPS for each electric company by using data envelopment analysis (DEA) and fuzzy c-means clustering (FCM). A new method for designing of RPS based Yardstick theory is proposed in [14].

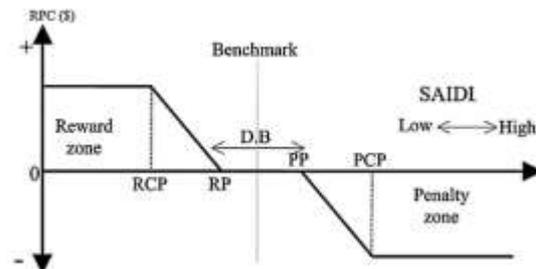


Fig. 1 A general RPS

On the other hand, the global trend today is a movement towards a more efficient electric distribution system and optimal utilization of available resources, in which asset management plays a decisive role [15]. Asset management should contain strategic planning, maintenance, utilization, and operation of a physical resource. The major challenge for a distribution company is to optimally manage its assets along with its objectives, considering that there is a battle between improving service reliability and controlling costs. Possible time scales of asset management are real time, short term, midterm and long term [16]. From a practical standpoint, there are inter-relations between the aforementioned timescales, additionally it is known that the coordination of an asset management’s timescales plays a critical role in strategic

decision making because actions occurring within each timescale interacts [17].

In all of the regulation strategy, this coordination has not been considered. With regard to this issue, in this paper, as shown in figure 2, a comprehensive separated regulation mechanism is presented so that the total expenditure for asset management is separated to capital expenditure (Capex) and operational expenditure (Opex). The separate Capex and Opex regulation is proposed for efficient electric distribution company regulation.

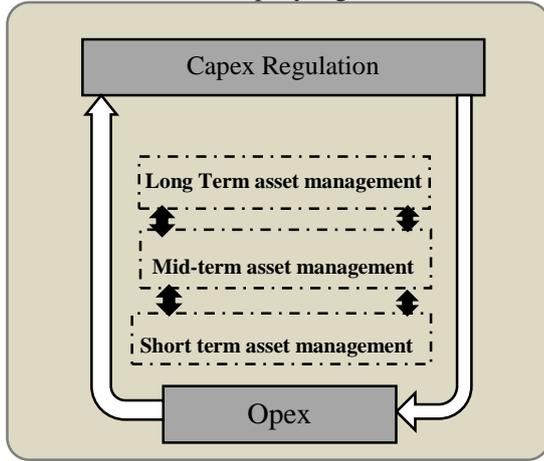


Fig. 2 separated regulation mechanism

PROPOSED METHOD

This paper considers short and long term asset management and a comprehensive separated regulation mechanism of a Distribution Company. The general framework of the proposed method is shown in figure 3. The main objective of this paper is to determine the optimal level of Opex and Capex as well as RPS parameters. In this regard, at first similar companies are clustered by fuzzy clustering method (FCM) based on factors that are outside the control of the companies into different groups. [13] The variables used for carrying out such classification are based on weather conditions and network conditions. These variables are maximum temperature ($^{\circ}\text{C}$), minimum temperature ($^{\circ}\text{C}$), precipitation (mm), average wind speed (knot) and number of days with thunder, density [number of customers per service area (C/km^2)] and quantity of energy supplied (MWh).

Then the optimal level of Opex of the i th year is determined by the following equation:

$$Opex_{opt,k}^i = Opex_k^i \theta_{o,k}^i \quad (1)$$

Where, $Opex_{opt,k}^i$, $Opex_k^i$ and $\theta_{o,k}^i$ are the optimal level of Opex, operational cost and efficiency score of k th DisCo respectively. The efficiency score is computed by data envelopment analysis (DEA) by considering operational cost as the input and the energy, number of customers and peak load as the output of DEA [13]. Once the optimal

Opex is determined the RPS parameter is calculated as the following.

Centre of dead zone (CDZ): this parameter is determined by the following equation:

$$CDZ_K = Ave_K \times \left(1 + \frac{RI_{\max}(\theta_{\max,j}^{cdf} - \theta_k^{cdf})}{(\theta_{\max,j}^{cdf} - \theta_{\min,j}^{cdf})} \right) \quad (2)$$

Where j denotes the cluster of the company, Ave_K is the historical average reliability index of company k , maximum reliability index improvement and θ^{cdf} is the efficiency score which is calculated considering customer damage cost as the input of the DEA method.

Dead zone width: In this paper, it is determined to equal the average SD of the historical reliability index for each cluster [18].

Max penalty and reward: these parameters are determined as proposed in [13].

Reward and penalty ramp: The main objective of this paper is to improve the quality of companies with low-quality levels and to prevent the deterioration of the level of quality. In this paper the reward and penalty ramp is determined by the following equation:

$$RS = \frac{\partial CIC}{\partial RI} \quad (3)$$

Where CIC is customer interruption cost and RI is the reliability index. The annual customer interruption cost (CIC) can be estimated with the method proposed in [19].

The optimal level of Capex is determined in the end of the regulatory period by the following equation:

$$Capex_{opt,k} = Capex_k \theta_{c,k} \quad (4)$$

Where, $Capex_{opt,k}$, $Opex_k$ and $\theta_{c,k}$ are the optimal level of Capex, capital expenditure and efficiency score of k th DisCo respectively. The efficiency score is computed by data envelopment analysis (DEA) by considering operational, capital and customer interruption costs at the regulatory period as the input and the energy, with the number of customers and peak load as the output of DEA[13].

CASE STUDY

The proposed method is tested on the Iranian distribution companies. There are 39 electricity distribution companies in Iran and the information of these companies is available at: www.tavanir.org. Other required information is taken from [13]. Due to the page constraint the regulatory period considered is 4 years and the results are determined for the first cluster of the result of [13]. The results of this paper is shown in table 1.

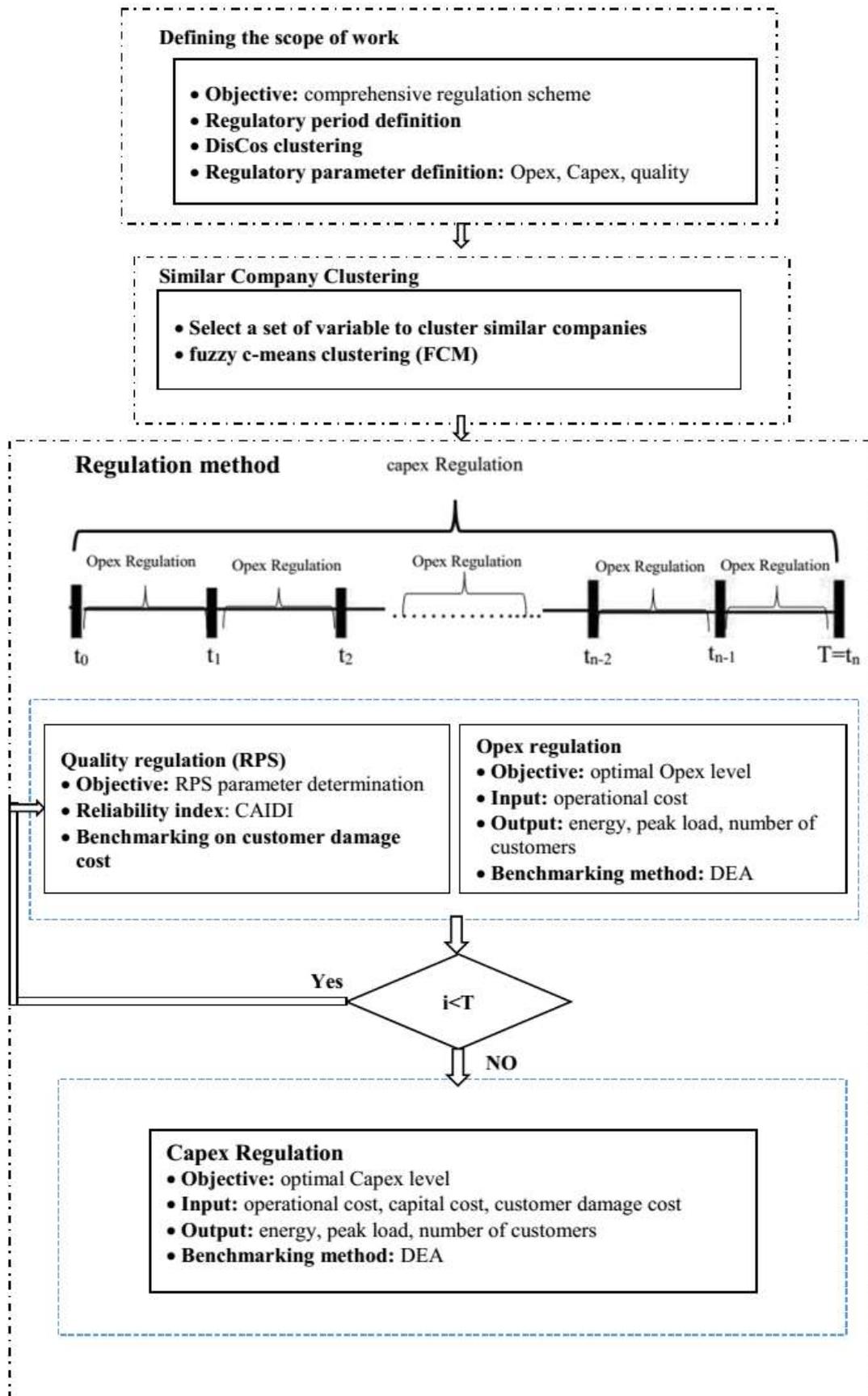


Fig 3 general framework of the proposed regulation method

Table 1 the result of the proposed method

Company	optimal	reward and penalty scheme					optimal
	Opex (M\$)	CDZ (min)	SD (min)	RS (M\$/min)	Max_P (M\$)	Max_R (M\$)	Capex (M\$)
A ₁	11.24	342	158	0.012	-1.818	1.371	13.92
A ₂	16.32	364	158	0.028	-5.926	2.870	22.45
A ₃	10.54	215	158	0.0101	-0.853	0.141	17.14
A ₄	15.63	589	158	0.014	-1.504	1.504	21.16
A ₅	42.80	2724	158	0.032	-2.275	2.275	28.18
A ₆	16.45	653	158	0.028	-3.882	1.969	17.16
A ₇	13.24	371	158	0.015	-2.758	1.764	17.14
A ₈	15.87	436	158	0.022	-2.854	0.270	20.24
A ₉	28.42	1734	158	0.036	-3.877	3.877	34.32
A ₁₀	12.22	501	158	0.042	-2.793	2.793	10.8
A ₁₁	11.23	396	158	0.013	-4.535	3.267	14.64
A ₁₂	9.62	842	158	0.013	-7.773	5.346	22.43
A ₁₃	15.26	1045	158	0.011	-2.613	2.613	12.42

In this table, parameters of RPS and optimal level of Opex and Capex are shown. The average SD for the considered cluster is 158 min and the width of the dead zone is equal to this value. Using the formula of (2) and (3) the centre of dead zone and ramp of reward and penalty scheme is determined for each company respectively. Other parameters of RPS are determined based on the [13]. The Optimal level of Opex and Capex is calculated based on each distribution company efficiency score and the real cost.

CONCLUSION

To provide an incentive, PBR is introduced to motivate the DSOs to improve the quality and efficiency by increasing the reliability index and decreasing the operational and capital costs respectively. Distribution companies use different asset management strategies to achieve this objective. Due to the inter-relations between timescales of asset management, the integration of timescale impact on regulation strategy plays a critical role. With regard to this issue in this paper, the total cost of each company was separated to the operational, capital and customer interruption costs. Then the DEA was implemented on the distribution companies in three steps and based on the efficiency score which was calculated with each step having the optimal level of Opex and Capex as well as efficient parameter of the reward and penalty scheme determined. The proposed algorithm creates financial incentives for distribution companies to improve or maintain their quality levels on one hand, and control their operational and capital costs on the other. Also the long term investment will be optimally done as it is required.

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