The Values of Incentive Regulations and Comprehensive Framework for Electrical Asset Management: An Iranian/Tehran Province Perspective

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Abstract

Asset management framework and its incentive economic equations are represented in this paper. To this end, asset management process conducted to realize distribution targets, are considered and a comprehensive framework of these activities is represented. This framework can be utilized in planning and evaluation of distribution system. On the basis of asset management comprehensive framework, economic equations are formulated and regulation indices are determined. Afterwards, method that regulates key indices is described. This method is conformed to distribution targets. At the final step, numerical studies on Tehran Province Regional Electrical Distribution Company (TPREDC) are presented. In TPREDC activities were done with few incentives, therefore productivity and benefit had reduced. After implementation of proposed internal regulation, it can be seen that key indices have been improved.

Keywords: asset management, regulations, comprehensive framework, economic equations

1. Introduction

1.1 Research Necessity

Electrical Distribution System Asset Management (EDSAM) is very important to achieve economic stability of this system. Having various activities, a wide network and numerous external factors with high impact, much number of assets, effect of human factors as motivation and education, asset management is very complicated (Reza, Saeed, & Hassan, 2010; Reza, Saeed, & Farid, 2010). Thus, in order to improve the performance of distribution system, it is of crucial importance to analyze activities, reconstruct distribution management structure and also index based regulation for each process.

Management Separation and decentralization can make EDSAM easy. For example, asset management and marketing activities have to be separated in power distribution companies. For each part, distinct rules and regulations have to be compiled so that private companies responsible for each class of activities and have enough motivation to improve indications and investments. This technique needs rules, regulation, planning and supervision.

1.2 Litterateur Review and Comparison

Ref (Tanure, Tahan, & Lima, 2006) proposes a procedure and methodology for performance target setting related to continuity metrics in electricity distribution networks. Ref (Rudnick & Donoso, 2000) assesses the Chilean "model company" regulation that aims at making the private distribution monopoly compete with a reference efficient model company, through a "yardstick competition" approach. Ref (Jamasb & Pollitt, 2007) reviews the recent experience of the UK electricity distribution sector under incentive regulation. The aim of Ref (Kinnunen, 2006) is to study the ex post regulatory system in Finland in context of investment incentives. Ref (Jamasb & Pollitt, 2008) examines the incentive properties and related aspects of the reference firm model—Network Performance Assessment Model—as used in Sweden and compares this with frontier-based benchmarking methods. Ref (Frías, Gómez, Cossent, & Rivier, 2009) analyzes how traditional regulation of distribution system operators has to be improved to accommodate higher levels of distributed generation. In this paper, a new method for regulation of separated parts of Distribution Companies (DISCOs) has been presented.

In many studies, incentive regulations for improving services and efficiency are provided for distribution asset managers. Ref (Carvalho & Ferreira, 2005) uses a matured evolutionary-based application to search for the optimum tradeoff between individual quality of service and system reliability. It is becoming very important to be able to demonstrate and quantify the necessity and benefit of particular investment and operational decisions in electricity distribution systems, particularly in the context of service quality (Strbac & Allan, 2001). Ref (Giannakis, Jamasb, & Pollitt, 2005) presents a quality-incorporated benchmarking study of the electricity distribution utilities in the UK between 1991/92 and 1998/99. The objective of (Ajodhia, Schiavo, & Malaman, 2006) is to evaluate the effectiveness of this system by studying the effects of regulation on the electricity distribution industry and to identify scope for improvement of the regulation in subsequent regulatory periods. The statistical two-sample t significance test presented in (Li, Su, & Shen, 2009) can be used to determine the cause-and-effect relationships that exist between the covered rates and the reliability indices including public safety. However, this paper represents a comprehensive framework for asset management, leaving power business apart. This framework can be used in planning, inspection and evaluation of asset managers.

Some studies investigate planning, supervision and assessment of asset managers. Ref (El-Fouly, Zeineldin, El-Saadany, & Salama, 2008) presents a new planning optimization model for distribution substation sizing, and timing. Ref (Das, 2008) presents a genetic algorithm based fuzzy multi-objective approach for determining the optimum values of fixed and switched shunt capacitors to improve the voltage profile and maximize the net savings in a radial distribution system. In Ref (Kaur & Sharma, 2008), a generalized model for optimal multi conductor size selection in planning of radial distribution system planning is presented. Ref (Singh & Goswami, 2009) presents new methodology based on nodal pricing for optimally allocating distributed generation for profit, loss reduction, and voltage improvement including voltage rise phenomenon. The dispatch of capacitors in distribution systems for daily operation is investigated in Ref (Wu, Zhang, & Lo, 2009). This paper propose target base framework to plan, supervise and assess distribution system comprehensively and can be criteria in distribution system studies.

Some papers study economic relations of distribution studies. Ref (Lima, Noronha, Arango, & dos Santos, 2002) focuses on the distribution pricing methods and suggests one that is currently under development in Brazil. Ref (Arocena, Contín, & Huerta, 2002) analyses the distribution of benefits between firms and consumers due to the price regulation of the Spanish energy sectors (electricity, oil fuels and gas) during the decade 1987-1997. Ref (Lowry & Getachew, 2009) presents the index logic that underpins this rationale in North American plans and offers two statistical approaches—indexing and benchmarking—that play a role in determining industry and/or national productivity trends and economy and/or industry input price trends that are used to track the unit cost of the industry. The main methodologies used in electricity price forecasting have been reviewed in Ref (Aggarwal, Saini, & Kumar, 2009). Ref (Chandramohan, Atturulu, Kumudini, & Venkatesh, 2010) uses a non-dominated sorting genetic algorithm (NSGA) for reconfiguring a radial Disco to minimize its operating costs considering real and reactive power costs while maximizing its operating reliability and satisfying the regular operating constraints. In Ref (Ketabi, Alibabaee, & Feuillet, 2009), the production cost of reactive power and investment cost of capacitor banks were included into the objective function of the optimal power flow problem.

1.3 Research Questions

An important application of having a comprehensive framework for asset management in power distribution is using it in balanced economic equations to regulate separated parts of DISCOs. The criterion used to determine the relationships based on the expected distribution indices is quite flexible so that it can provide the asset manager with enough motivations to realize power distribution targets. Therefore, compared with other studies in this area, the proposed method has the following preferences:

- Comprehensive compilation of regulations and activities
- Balanced compilation of regulations and activities
- Compilation of regulations and activities in accordance with the targets of power distribution company

This paper contains the following sections: in the section 2, the targets of power DISCOs are represented. The framework of asset management is covered in the section 3. Section 4 includes comprehensive economic equations and motivations to regulate asset manager. Numerical studies in TPREDC conducted with proposed model in the section 5. Finally, section 6 covers the conclusions.

2. Distribution Targets

According to ref (Reza & Saeed, 2010), DISCOs are expected to operate as economic enterprises. Therefore, their targets are specified respecting the profits of their stakeholders. Major stakeholders of distribution

companies are customers, shareholders and the society, each of which has a different set of targets. Using the common language of asset, frameworks for power distribution tariffs, power market regulations and controlling tools are provided so that they can be easily utilized by distribution economic institutions in order to execute activities defined by the distribution asset management framework and also can guarantee the profits of the shareholders.

Distribution Company as an economic institution has to undertake the obligations defined by the government respecting the price determined in tariff strategy. This requires asset management planning in distribution system. Such planning suggests either developing the distribution network or keeping up with the current assets. In result, electricity targets, which can also be considered as power distribution targets, are expressed as follows:

- Best service or service improvement

- Min money or efficiency improvement

- Customer asserts and environment

Asset management targets have to comply with distribution targets. Thus, it requires various infrastructures to realize the mentioned targets. These infrastructures are divided into three major categories including engineering, information and management.

Distribution targets can be demonstrated as Figure 1, in which the targets restricting DISCO are removed and replaced by operational targets aimed at asset improvement.

In this section, structure of process implementation to realize distribution targets are investigated.

3. Asset Management Framework

Asset management mainly includes development and operation activities. Both of them have to be planned in a way that distribution targets are achieved in the most economic way. The diagram of asset management activities aimed to realize its targets are as represented in Figure 2.

As one can see, Figure 2 shows the general scheme of asset management. The corresponding Master Plan is provided in Figure 4.
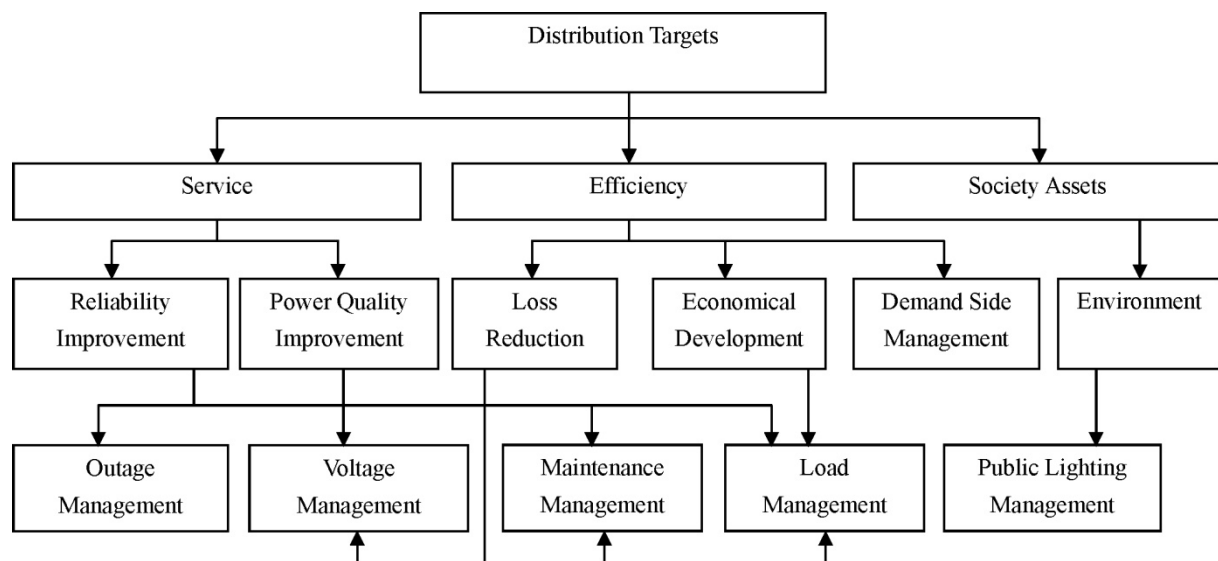

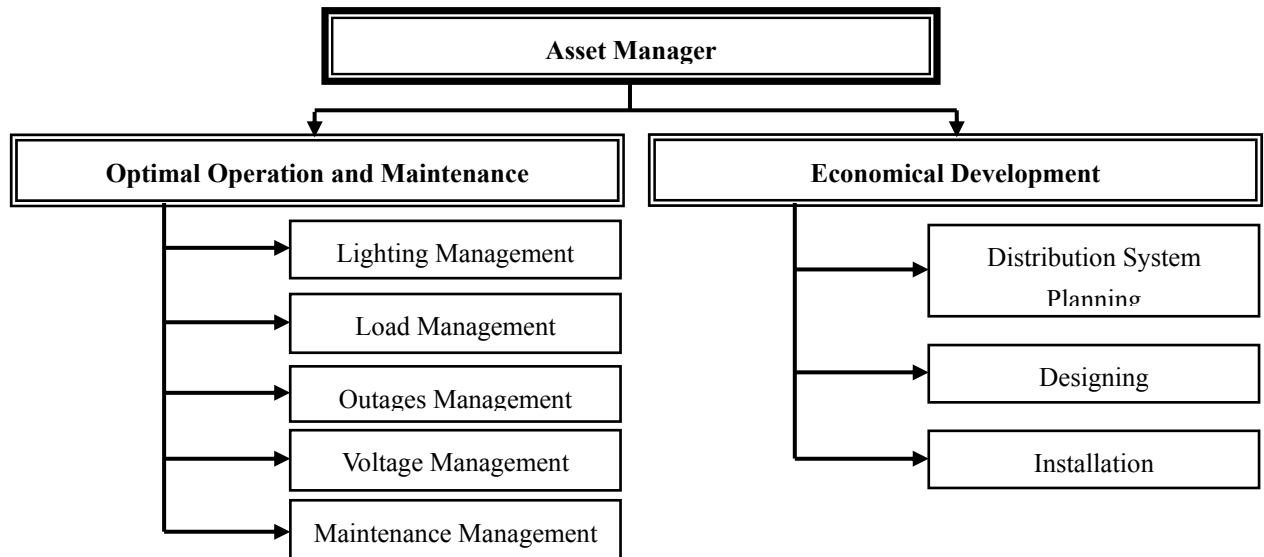Figure 1. Distribution targets implementation

Figure 2. Asset manager structure aimed to realize asset management targets

4. Asset Management Economic Equations

There are different scenarios regarding asset management:

Scenario1: In this scenario, planning is conducted by another company and the asset manager is only responsible for network operation. In this case, studies and plans are done based on three lines of time, human resources and financial resources. Moreover, financial and penalty records are defined according to the framework aimed to realize scheduled targets. This scenario is project-oriented and is applicable in outsourcing while the incumbency stays in distribution company.

Scenario2: This scenario tries to approximate asset manager equation to the power marketing equation. To this end, indices of increasing energy efficiency in power distribution are defined as the basic indices of the outcome of asset manager. Afterwards, the cost of increasing each unit of efficiency is determined by efficiency promoting activities. In this case, planning is undertaken by the asset manager. This scenario is result-oriented and the incumbency is granted to the asset manager.

The second scenario has the following benefits:

•   In medium- and long-term transfer of asset management to private sector, this sector conducts studies on investment and its rate of return and long-term planning. Consequently, huge investments are provided for asset management and thereby, indices are improved.

•   Regarding their nature, power distribution networks have to be constantly monitored and decisions have to be made locally. Thus, scenario 2 plays an important role in increasing the efficiency.

•   Outages and wastages of the power distribution network affect every aspect of distribution plans. Proposed method improves reliability indices and other distribution indices simultaneously. Therefore, outages and wastages are reduced with proposed method.

In this section, economic indices required to implement scenario 2 are designed. To this end, the indices related to distribution targets are defined based on the Table 1.

Table 1. Distribution targets and indices

	Service			Efficiency	Environment	restrictions
Distribution Targets	Voltage improvement	Reliability		Reduction of loss	Improvement of lighting	-
Corresponding indices	Complaints on voltage quality	Energy not supplied	Coordination with dispatching	Loss factor	lighting factor	Complaints and wastages

Some of the above-mentioned indices require investment and regulation while some other are considered as operational restrictions, which are of crucial importance in all classes of activities and targets. Using following function, restriction indices are calculated as a number between zero and one:

$\alpha = Fconstraint(the\ absence\ of\ reports, complaints, safety, etc.)$

However, investment compensation is calculated by function F using the following relation:

$F = Reliability\ improvement\ (F_1) + Loss\ reduction\ (F_2) + Lighting\ operation\ (F_3)$

$IC_1 = F_1(Reliability\ improvement) = (ET + PM\beta + LM\gamma) \times \theta \times E \times TO \times 10^{-4}(\$)$

$TO = (1 + \dfrac{scheduled\ energy\ not\ supplied}{E})$

$IC_2 = F_2(Loss\ reduction) = 3.5 \times LS \times E \times 10^{-4}(\$)$

$IC_3 = F_3(Lighting\ operation) = PUB \times (Lighting\ factor)$

LS: loss factor

ET: Cost of outage management per kWh

PM: Cost of maintenance management per kWh

LM: Cost of load management per kWh

β, γ: Supervision factor

E: Amount of energy delivery per kWh

TO: Indictor of scheduled outages and generation shortage

θ: Indicator of the reliability regulation, which is obtained using the following curve and relation

PUB: Cost of lighting management in terms of $

LS and θ have to be defined in a way that in addition to considering investment costs and providing satisfactory investment rate of return encourage the distribution companies to invest with the aim of improving the indices. Therefore, these functions are formed as described below.

$\Delta LOSS = \dfrac{loss_1 - loss_2}{E} \times 100$
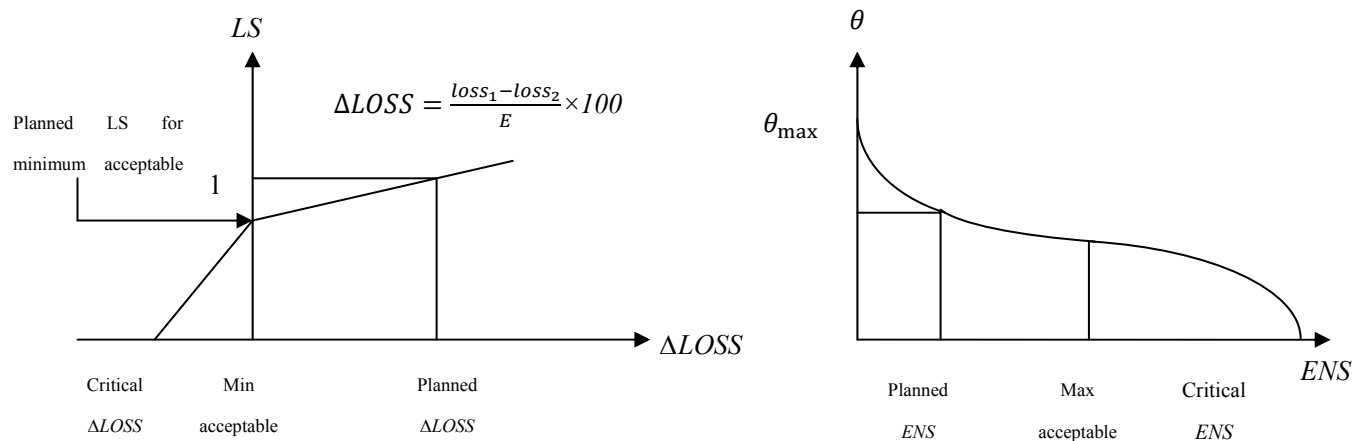
Figure 3. *LS* and θ function

As one can see, functions *LS* and *θ* play a key role in regulation the activities and encouraging the asset manager that manage with private sector to accurately plan the investments and optimal conduction of the processes. Thus, the following method is used to define *LS* and *θ*.
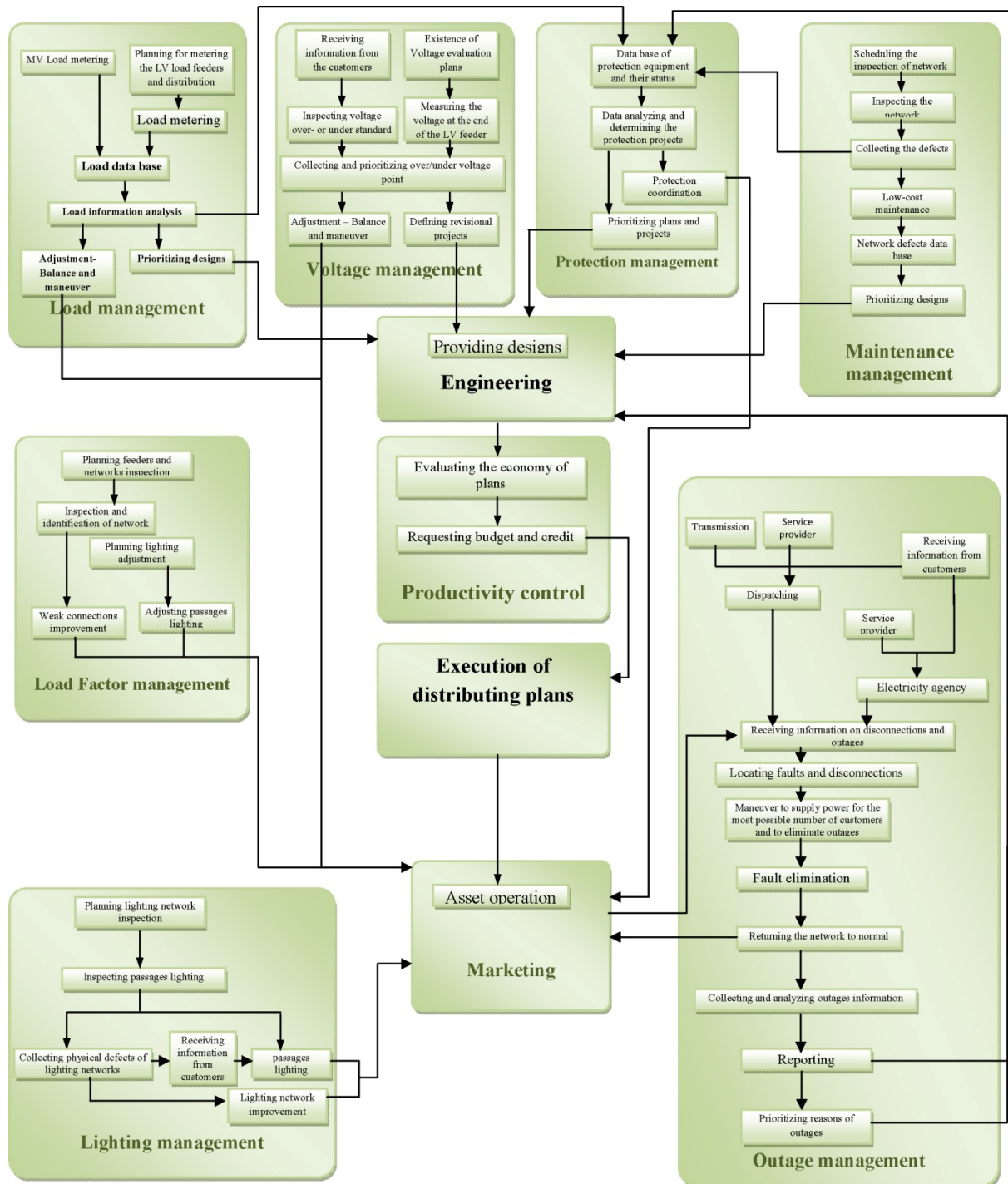

Figure 4. Asset management process

1- Determining the mount *Loss* and *ENS* in the last year.

2. Determining the target amount of *Loss* and *ENS* for the next year.

3. Determining the acceptable increment of *Loss* and *ENS* in the absence of investment

4. Determining critical amounts of *ENS* and *Loss*

5. Formulation

θ formula can be defined in three periods as follows that shown in Figure 3.

$$\theta = \begin{cases} \theta_{max} e^{a_1 \times ENS} & 0 \leq ENS \leq Previous\,ENS \\ a_2 \times ENS + a_3 & Previous\,ENS \leq ENS \leq Maximum\,acceptable\,ENS \\ a_4 e^{a_5 ENS - a_6} + a_7 & Maximum\,acceptable\,ENS \leq ENS \leq critical\,ENS \end{cases}$$

LS formula can be defined in three periods as follows and shown in Figure 3.

$$LS = \begin{cases} b_1 \Delta\,LOSS + b_2 & Maximum\,acceptable\,\Delta LOSS \leq \Delta LOSS \leq critical\,\Delta LOSS \\ b_3 \Delta\,LOSS + b_4 & Critical\,\Delta LOSS \leq \Delta LOSS \leq Maximum\,acceptable\,\Delta LOSS \end{cases}$$

Indices a_i in θ and b_i in *LS* regulate the investments aimed to execute the processes and grow with inflation rate. They reduce the costs that required improving distribution indices and depending on the acceptable, critical and last year amounts of *ENS* and *Loss*.

The three parts considered in functions *LS* and θ work in a way that threat the investor to stop investing and encourage him to invest.

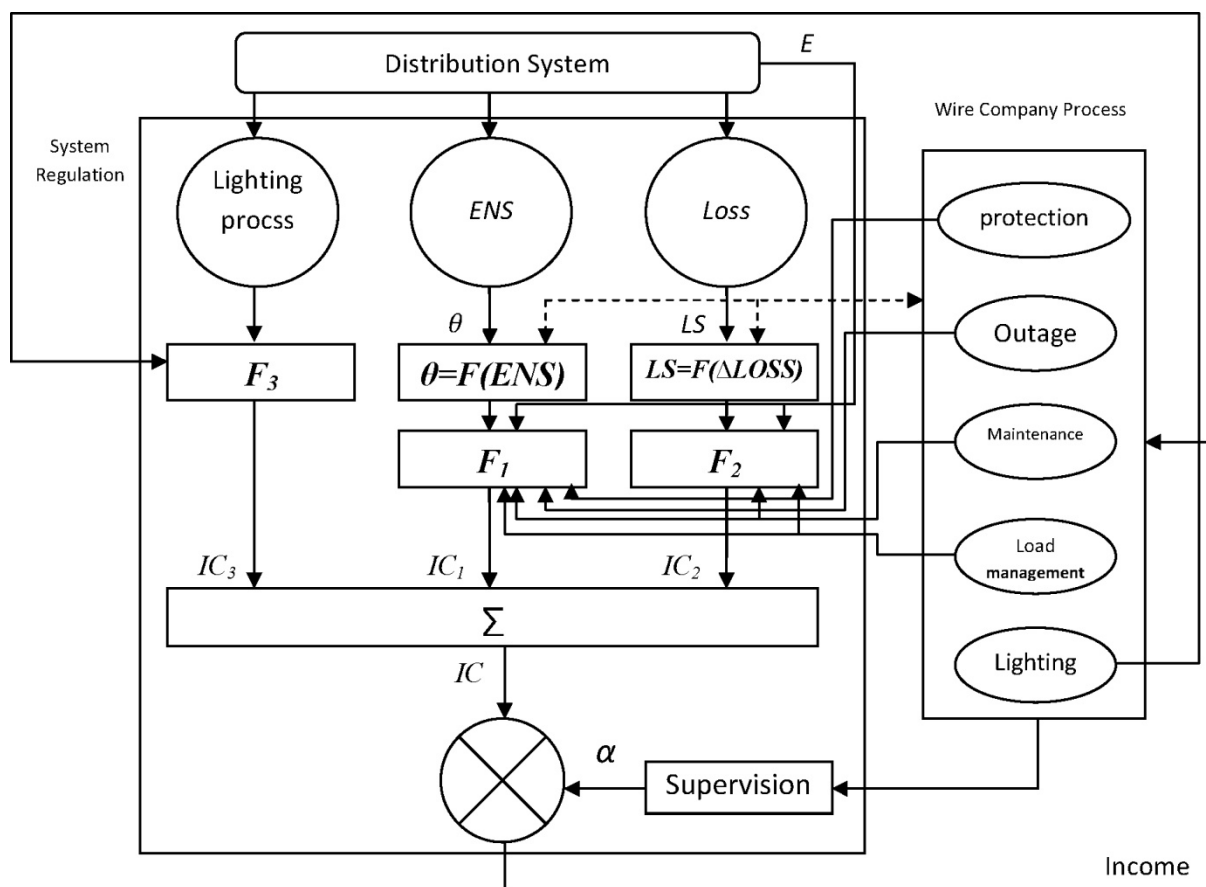In result, the method of regulation economic function works as follows:

Figure 5. Regulation economic function

5. Numerical Studies

Numerical studies were conducted in TPREDC and in Chahar-Dangeh region, the information of which is represented as follows. The current state of indices and next year targets for Chahar-Dangeh region is as follows. Thus, parameters of functions LS and θ are determined using following equation:

Table 2. Equipment used in Chahar-Dangeh region at the end of 2008

No.	Equipment	Unit	Quantity
1	Area of Chahar-Dangeh	Square Kilometers	134
2	Number of customers	Customer	33354
3	Number of personnel	Person	19
4	Number of air substations	Substation	1350
5	Number of ground substations	Substation	95
6	Length of air medium-voltage line	Kilometer	390
7	Length of ground medium- voltage line	Kilometer	36
8	Length of air low- voltage line	Kilometer	630
9	Length of ground low- voltage line	Kilometer	240
10	Number of public medium-voltage feeders	Feeder	36
11	Number of low- voltage feeders	Feeder	3080

Table 3. Result of asset management regulation

	Real data in 2009	Planned data for 2010
LOSS	26.7	24
ENS	1.99	0.9
Lighting factor	0.92	0.93
Safety	1	-
compliant	27	10

$\theta_{max} = 1.35$

Planned *ENS*=1

Maximum Acceptable *ENS*=2

Critical *ENS*=8

$a_1 = -0.3$, $a_2 = -0.1$, $a_3 = 1.1$, $a_4 = -1.1$, $a_5 = 0.0625$, $a_6 = -0.125$, $a_7 = 2$

Planned $\Delta LOSS$ = 2

Minimum Acceptable $\Delta LOSS$=0

Critical $\Delta LOSS$ = -2

$b_1 = 0.95$, $b_2 = 1.9$, $b_3 = 0.0125$, $b_4 = 0.95$

After implemented in Chahar-Dangeh, indices changes as Figure 6. As one can see, the above-mentioned relations provide the asset manager with sufficient motivation to improve indices and thereby, distribution targets have been improved.
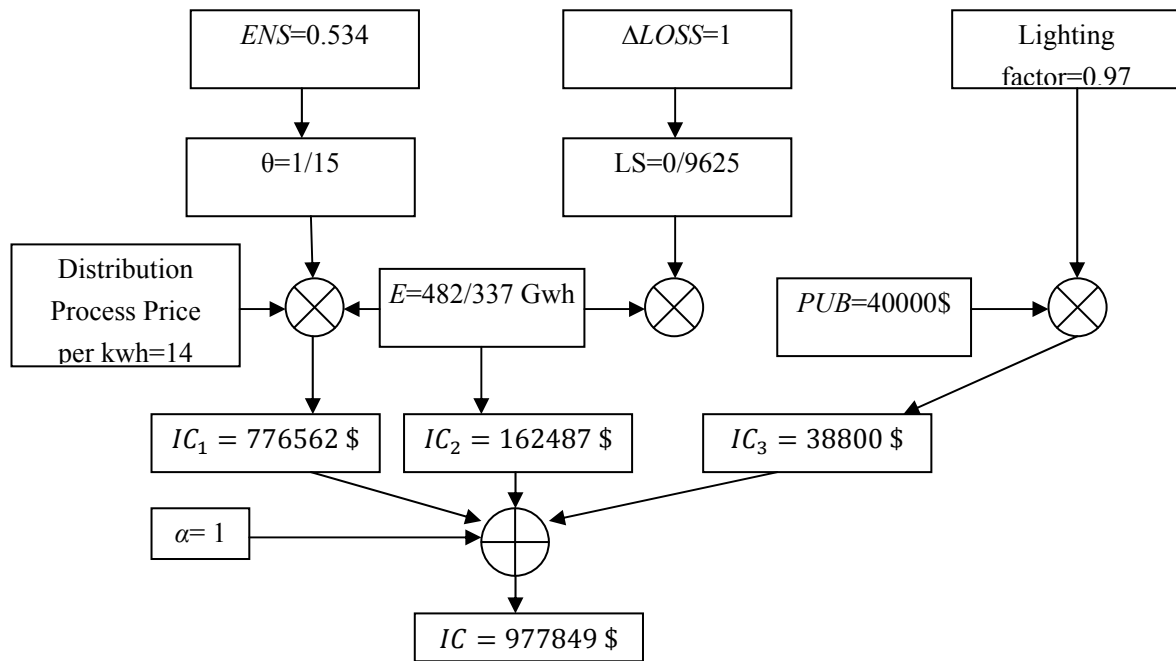
Figure 6. Numerical results diagram

6. Discussion

Results Shows that we must separate the parts of Distribution activities and regulate them with economic equations. This task can motivate system's player to improve their process. Also faults, system's defects and improvable points can be found easily. Proposed model can be used to price cap regulation and marginal cost reduction through indices planning. Also proposed model can be applied to meter external factors' effects and therefore manage them.

7. Conclusion

This paper represented a comprehensive framework for asset management activities. This framework provides the means to plan and evaluate the promotion of distribution targets. Using the represented framework, asset management economic equations were clarified and important indices of increasing the incentives of the asset manager company were determined. In the proposed method, distribution targets and the corresponding indices were used as the criterion of tuning the indices so that the distribution targets can be tuned by specifying the required regulations. Thus, distribution targets, activities and indices can be promoted and controlled using this method. At the final step, the method was implemented in a sample region and the results indicated the sensible improve of indices.

Comprehensive, balanced and target-compatible tuning is of the benefits of the proposed method over other methods. This method improves customer services, increases efficiency and leads to energy distribution in the most economic possible way.

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