EFFECT OF FINANCIAL AND TECHNICAL UNCERTAINTY ON DISTRIBUTION NETWORK RECONSTRUCTION PROJECT SELECTION

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ABSTRACT

Distribution companies are pressurized into investing in many projects for ensuring customer satisfaction and increasing their profitability. There are a lot of feasible projects that may help companies to improve their services, but resources for accomplishing them are limited. Therefore, financial subjects are crucially important for related decision making and budget allocation is a bone of contention between different departments of companies. Project net present value (NPV), which depends on investment, expected annual profit, interest rate and inflation rate, is realistic criterion of project economic value. Interest rate and inflation rate are not predefined coefficients. Consequently, there is a great deal of uncertainty about NPV. In addition, the projects related to the new technologies or components are not promising. This paper is focused on the effect of uncertainty, especially future energy price and successfulness of project, on projects NPV. Our case studies substantiate the claim that a great many of attractive projects will not be profitable unless the energy price considerably increases over time, especially in developing countries with high interest rate.

INTRODUCTION

Budget allocation, the distribution of financial resources among competing Projects, is controversial issue in distribution companies. Although a great many mathematical programming methods for budget allocation have been developed, engineers have not reached a consensus on how they should allocate their limited financial resources to their expenditure like distribution network construction and maintenance costs. Especially, medium voltage network reconstruction is long-term investment which requires considerable funding.

Net present value (NPV) which is defined as the difference between the present value of cash inflows and the present value of cash outflows can be used for analyzing the profitability of an investment or project. Three issues should be considered in economics evaluation of distribution network projects: First, the future worth and net present worth depend on interest rate and electricity price in long-term, which could not be predicted accurately. Second, the effectiveness of network reconstruction projects which are related to improving reliability indices, especially innovative plans, is not clear. In these projects, probabilities of predefined goal achievement are neither known nor can be calculated. Therefore, uncertainty level of success should be considered in relevant studies. Third, distribution companies try to archive many goals. Therefore, selecting optimal combination of possible projects is not pure economical issue; in contrast, it is multi-objective optimization needed proper decision making approach. Thus planning strategy should be based on quantitative measurements of profitability, estimation of cash flows, systematic comparison of alternatives and selecting optimal combination of projects. If funds placed in a reasonable investment, its value will increase, depending on the elapsed time and interest rate. In contrast, when interest rate is considerably greater than energy inflation rate, investing in some network reconstruction project is not profitable.

As highlighted in the previous paragraphs, it is not possible to calculate profitability of each project accurately. Therefore, we have focused on estimating the net present value of alternative projects by simulation and uncertainty study. In this project many network projects in three zones have been selected and their effect on power loss, energy not supplied (ENS), expected number of outage per year and expected duration of outage have been estimated by computer simulation under optimistic and pessimistic conditions. Afterward, maximum, minimum and expected net present worth of each project under these conditions with various interest and inflation rates have been calculated. Optimal combination of network reconstruction plan can be selected by mathematical programming.

NET PRESENT VALUE AND PROFITABILITY INDEX

The "time value of money" concept indicates that there is a meaningful difference between the "present value" and "future value" of same cash flow. Discounted cash flow (DCF) analysis is a method based on time value of money for assessing projects. In this approach all future cash flows are discounted to their present values. To calculate the present value of any cash flow, it is divided by interest rate plus one for each period of time. [1], [2]

$$PV = \frac{FV}{(r+1)^t} \qquad (1)$$

PV: Present value
FV: Future value
r: Discount rate

t: Number of time period

Net present value (NPV), also known as net present worth (NPW), is the most widely used method for evaluating long-term projects. NPV is summation of present value of all cash outflows and inflows of project and shows the value that an investment or project added to the firm. In other words, NPV is the difference between the present value of cash inflows and the present value of cash outflows. Future cash flows are discounted at the discount rate, and the higher the discount rate, the lower the present value of the future cash flows. So determining the proper discount rate is vitally important for properly valuing future cash flows.

If NPV is positive the related project is profitable, but if this value is zero or negative, although the project has not monetary value, decision could be based on other criteria which are not included in the calculation such as company reputation or customer's satisfaction.

The profitability index, which is the ratio of the project net present values divided by the investment initial cost, is a measure of the value of a project compared to its cost. Therefore, it is reasonable to allocate their finite budget to the most profitable projects (Highest PI).

$$PI = \frac{NPV}{Investment} \qquad (2)$$

PI: profitability index

The economic evaluation of projects is not limited to NPV method. Although there are many effective techniques like internal rate of return (IRR) or benefit/cost (B/C) which can be used for assessment, NPV is chosen in this paper because of its compatibility to mathematical programming tools such as integer programming and goal programming.

PROJECTS FINANCIAL AND TECHNICAL UNCERTAINTY

Investment under uncertainty is one of the most controversial decisions that distribution companies make. A lot of electric component have been used in electrical distribution network. These components wears out and their reliability gradually will be reduced, so we should consider their physical and economic life time.The physical life of an component represents its maximum life at which it wear out and should be replaced and the economic life of component is the length of time which it can be used economically. Managers can invest in a new network or expansion of existing one or keep them and invest only in maintenance.

Although, there are many sources of uncertainty in distribution network decision making, we focus on four types of uncertainty: demand, interest rate, energy price and project effectiveness uncertainty. The ENS and power loss reduction is strongly related to network load, so energy demand change has an effect on distribution network projects profitability.

Previous researches have shown that there is meaningful relation between interest rate, interest rate volatility and investment. A higher interest rate level will reduce investment demand and interest rate volatility increment will make it profitable for a company to postpone its investment decisions. In addition, although increase in the expected demand growth rate normally leads to higher investment, increase in its volatility always reduces the accumulation rate [3-6].

The last source of uncertainty is the effectiveness of executing selected project. Many factors have an impact on project effectiveness. Sometimes distribution companies try to use new technologies or innovative components, but their prerequisites are unnoticed or ignored. For example, procurement department of company buy new components but contractors have not been informed about related standards, training and necessary tools and accessories. In addition, the long-term reliability of many new components and technologies is unknown.

PROBLEM DESCRIPTION

A section of medium voltage distribution network which is selected for current study consists of 20km overhead line and 200m underground cable and supplies 29 distribution transformers. The majority of conductors used in this network are Mink and Heyna, but there are smaller size conductors too. Three segments of overhead network have been selected for upgrade: zone 1 (1925 meter), zone 2(942 meter) and zone 3(3695 meter). There are many option for network enhancement, including higher diameter bare conductor, cover wire and underground cable. It is possible to combine two projects (e.g. use cover wire with higher diameter) but only 700milion Rials (20000Rials = $1) can be allocated for this project and total investment should not exceed this budget.

For each feasible project, binary variable has been defined:

X_1: replace Mink bare conductor with Heyna (zone 1)
X_2: replace Mink bare conductor with Heyna (zone 2)
X_3: replace Mink bare conductor with Heyna (zone 3)
X_4: use cover wire with same diameters (zone 1)
X_5: use cover wire with same diameters (zone 2)
X_6: use cover wire with same diameters (zone 3)
X_7: use 185mm^2 underground cable (zone 2)

Required investment for underground cable in zone one and three exceeds available budget.

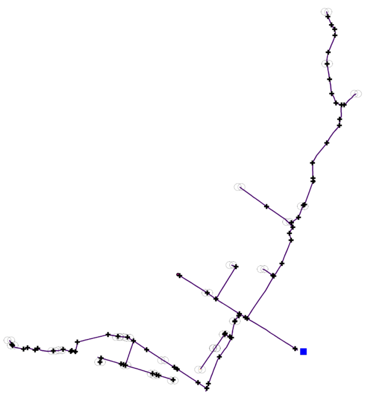

Figure 1: Network selected for reconstruction

RESULT AND DICUSSION

Effects of network upgrade have been calculated by software simulation. In the following tables and figures monetary unit is million Rials and energy unit is MWh. The result of simulation with fix electrical energy price can be found in table1 (discount rate =%19, all uncertainties have been neglected). The net present value of projects is negative, because discount rate in Iran is rather high and increment in energy price should not be neglected. The NPV of projects with various electrical energy inflation rates have been shown in table 2.

Using cover wire is a rather new technology in Iran and the reliability of covered wire networks erected by some contractors are not as good as predicted indices, because of insufficient crew training and use of poor accessories. In addition the life time of accessories are not known. The simulations have been repeated after focusing on technical uncertainty and its result can be seen in table 3. Majority of network upgrade projects will be unprofitable when long-term energy price inflation rate is less than 13%. If inflation rate is above 16%, the number of profitable projects will be increased and if this rate exceeds 22%, all projects NPV except two projects will be positive. X_7 is related to underground cable and its excessive starting investment never return. X_3 is rather elongated branch supplying few small customers. Therefore investment on power loose reduction is not reasonable.

Table 1: Effect and net present value of projects (Fixed energy price)

	Investment	Salvage	Reduce expected ENS	Reduced power loose	NPV
X_1	77.1	9.18	1.71	0.96	-65.9
X_2	37.8	4.5	0.84	1.36	-31.6
X_3	148	17.9	3.28	0.41	-127
X_4	67.3	9.18	6.44	0	-53.1
X_5	32.9	4.5	3.16	0	-26.0
X_6	129	17.9	12.4	0	-101
$X_{1,4}$	121	9.18	8.1	0.96	-104
$X_{2,5}$	59.4	4.5	3.99	1.36	-50.8
$X_{3,6}$	232	17.9	15.6	0.41	-201
X_7	518	4.5	4.93	1.98	-508

After combination of economic and technical uncertainties, the range of net present value of each project has been determined and shown in figure 1. The upper and lower end of vertical lines is related to minimum and maximum net present value that can be achieved in extreme conditions. The top and bottom of the boxes show the third and first quartile of NPV and small circles present expected net present value. Under equal condition, it is preferable to select project with higher Expected net present value and smaller NPV variation.

In reality, it is not reasonable to confine decision criteria to long-term economic profitability. There are other factors that have influence over customer satisfaction and company reputation. The effect of projects on other factors is shown in figure 2. There are many approaches for selecting optimum set of projects including weighted sum integer programming, weighted sum goal programming, lexicographic goal programming and fuzzy programming. Weight of each criterion in final decision can be determined by multi criteria decision making (MCDM) methods like analytic hierarchy process (AHP) and TOPSIS.

Table 2: NPV of projects (inflation is included)

Inflation rate →	10%	13%	16%	19%	22%
X_1	-47.1	-40.7	-31.0	-15.7	8.69
X_2	-16.2	-10.9	-2.93	9.63	29.7
X_3	-101	-92.5	-79.1	-58.1	-24.4
X_4	-7.93	7.4	30.8	67.6	126.4
X_5	-3.79	3.73	15.23	33.26	62.14
X_6	-14.5	14.9	60.1	130.9	244.2
$X_{1,4}$	-41.2	-19.7	13.3	65.0	147.9
$X_{2,5}$	-13.2	-0.50	18.9	49.4	98.3
$X_{3,6}$	-89.4	-51.3	6.94	98.3	244.6
$\mathbf{X_7}$	-460	-443	-418	-379	-315

Table 3: NPV of projects (inflation and technical uncertainty is included)

Inflation rate →	10%	13%	16%	19%	22%
X_1	-47.1	-40.7	-31.0	-15.7	8.69
X_2	-16.1	-10.9	-2.93	9.63	29.7
X_3	-101	-92.6	-79.1	-58.1	-24.4
X_4	-18.4	-6.22	12.33	41.43	88.04
X_5	-9.01	-3.08	5.98	20.19	42.94
X_6	-35.1	-11.9	23.65	79.34	168.5
$X_{1,4}$	-51.4	-32.9	-4.63	39.68	110.6
$X_{2,5}$	-18.4	-7.32	9.71	36.42	79.19
$X_{3,6}$	-106	-72.7	-22.05	57.32	184.4
$\mathbf{X_7}$	-460	-443	-418	-379	-315

CONCLUSION

Economic and technical uncertainties have considerable effect on distribution network reconstruction and upgrade decision. Company budget could be wasted if this matter is neglected or decision criteria are confined to short-term economic items. Therefore, the effective combination of technical and economical issue can help engineers to select optimum set of projects which are profitable in long-term.

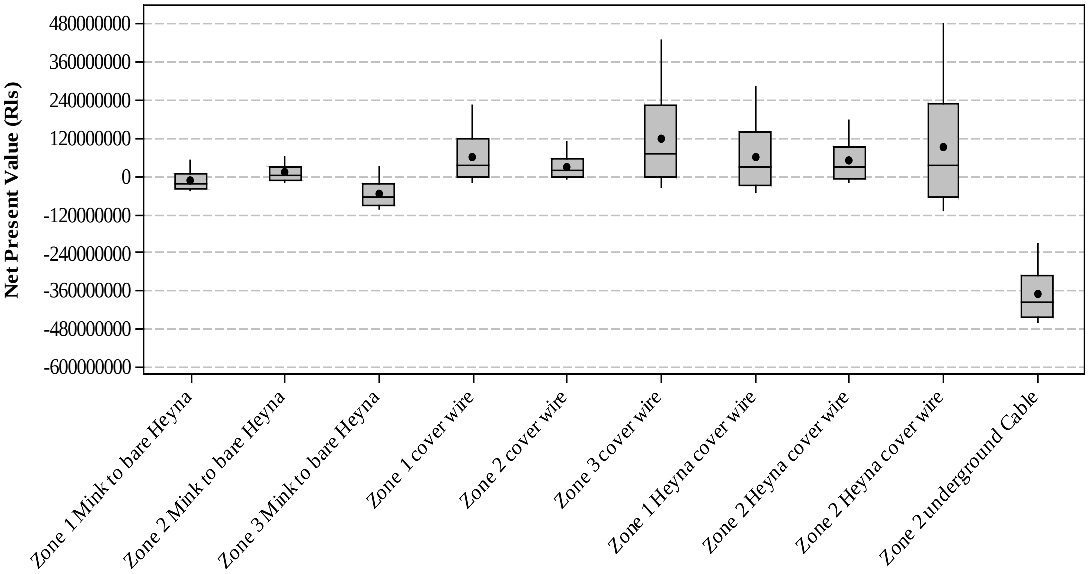

Figure 1: variation of projects NPV

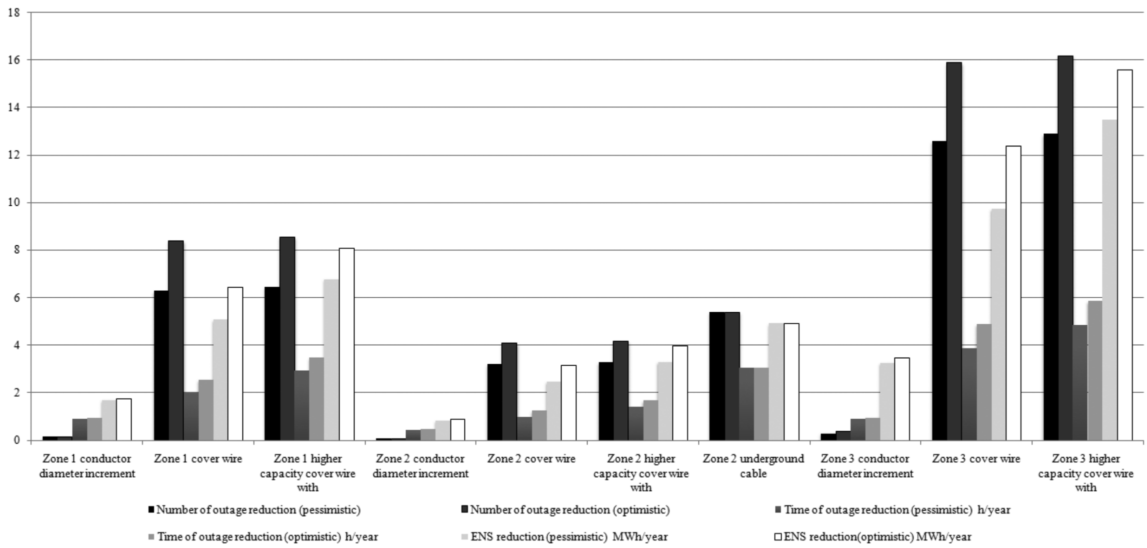

Figure 2: Effect of projects on outage and expect ENS

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