ANALYZING THE EFFECT OF TRANSFORMER UTILIZATION FACTOR IN DISTRIBUTION NETWORKS AS AN INVESTMENT MANAGEMENT INDEX BY USING DISPLAN SOFTWARE

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ABSTRACT

Distribution transformers are one of the most expensive devices in distribution networks. Finding the appropriate location and size of these transformers could extremely influence the total investment of the network. The utilization factor value of the transformers can play a significant role in sizing and locating them in design and operation stages of the network. Generally, it is assumed that any increase in the utilization factor of the transformers can lead to a decrease in the required investments in distribution systems. However, it seems that the distribution network structure and geographical pattern of the electrical loads may affect the appropriate value of the transformer loading and its related utilization factor. This topic is investigated in this paper to obtain the optimal value of the utilization factor via studying two real cases with different structural specifications and load types. The optimum designs of these two networks with different values of the transformer utilization factors are provided using the DisPlan software and the results are presented and the effect of utilization factor is discussed in detail..

INTRODUCTION

Uncertainty exists in the variation of electrical loads in distribution systems causes that the load predictions do not always correspond to the real values. This may lead to overloading condition of transformers in such systems [1]. Hence, the network planners usually decide to devote more capacities for transformers than what is required for serving the loads to accommodate the load random excessive increment. This decision in design stage is equivalent to selection of lower values than 1 for utilization factors of transformers. In this way, the value of the utilization factor of transformer can affect the size of transformer that is required for supplying a specific set of electrical loads and accordingly, the total number of transformers which are needed to serve all of the loads.
The value of utilization factor of transformer can also affect the lifetime of the transformer by limiting the loading level in operation period and, it can even provide a reserve capacity to supply uninterruptable loads in the low voltage network through maneuvering in the low voltage feeders.

Since higher values of the utilization factors mean lower investments in transformer installation inside the network, the private owners of distribution systems try to more exploit the network equipment capacity because of the more benefits. However, it seems that the distribution network structure and geographical pattern of the electrical loads may affect the appropriate value of the transformer loading and its related utilization factor.
Hence, this topic is investigated in this paper to obtain the optimal value of the utilization factor via studying two real cases with different structural specifications and load types. The optimum designs of these two networks with different values of the transformer utilization factors are provided using the DisPlan software and the results are presented and the effect of utilization factor is discussed in detail. DisPlan is advanced specialized software in optimal design of the electrical distribution networks.
This new software is used to design the distribution networks of these two case studies for different values of transformer utilization factor and provide a lot of information about the designed network quantities such as the value of the investment costs, the power loss and the energy losses, and the outage duration.

METHOD OF ANALYZING THE EFFECT OF TRANSFORMER UTILIZATION FACTOR

In order to analyze the effect of transformer utilization factor in the total distribution network plan, it is necessary to provide a procedure to produce optimal plans for the system under study based on a unique approach. The unique approach for the optimal planning of the distribution network should yield the minimum investment and also the minimum operational costs during the lifetime of the network while not violating the technical constraints such as voltage drops and allowable current limitations inside the network.Generally, the main decisions during the optimal planning of a distribution network for an understudy area can be listed as follows:

- Optimum location of transformers
- Optimum capacity of transformers
- Optimum path of medium and low voltage feeders
- Optimum capacity of feeders

Which is subjected to minimization of the investment cost and operational cost (e.g. cost of energy losses, repair and maintenance costs, etc.).

Now, it is possible to assess the effect of different values of the transformer utilization factor using the aforementioned framework for optimal planning of distribution systems. A methodology for optimal planning of the distribution systems satisfying the objectives and constraints of the aforementioned framework was already studied in detail by authors in recent years [2 – 4]. These studies led to DisPlan which is software for optimum planning of distribution networks [5]. Using DisPlan, it is enabled to provide different optimal plans; each one has its own transformer utilization factor value. In addition, it is possible to evaluate the resulting optimal plans from the viewpoint of different cost terms and the technical features of the plans such as the energy loss value, the network structure and so on. This task is accomplished in two real cases in the following sections of this paper.

CASE STUDIES

Case studies of this paper consist of two different types of distribution networks namely, urban distribution network and industrial distribution network. The brief specifications of these two case studies are mentioned in Table 1.

TABLE 1. Case studies specifications

Case study	I	II
Area type	Urban	Industrial
Type of loads	Residential, commercial	Industrial, administrative
Number of customers	811	61
Total load [MW]	1	21.7

Urban distribution network

This case study is about an urban area in Karaj city, Iran. The load prediction studies yield a value of 3% per year for the load growth of this area. Accordingly, the total load value (active power) of this case study after 5 years would be about 1 MW. The input data of this area was entered into DisPlan and several plans including medium voltage network and low voltage network are provided for this network based on different values of transformer utilization factor. In this regard, the transformer utilization factor changes from 0.5 to 1.0 in 0.05 steps. For instance, the optimal plans of the understudy area with the value of 0.75 for transformer utilization factor are shown in Figs. 1 to 2 and the planning results are displayed in Fig. 3.

Since the transformer utilization factor directly affects the total investment of the network, the network investment value and the network power loss value are used as the comparison parameters between different plans. The planning results for different parts of the network cost for the understudy system with different values of transformer utilization factor are depicted in Figs. 4 to 7. Also, the trend of the power loss variation in these plans is also pictured in Fig. 8.

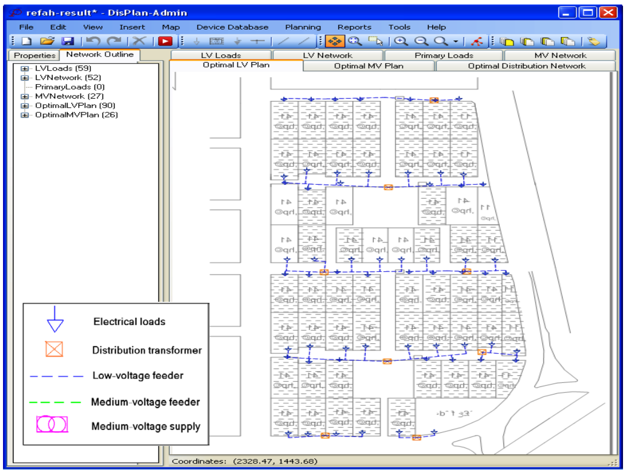

Fig. 1. Optimal LV network of the urban area with transformer utilization factor of 0.75

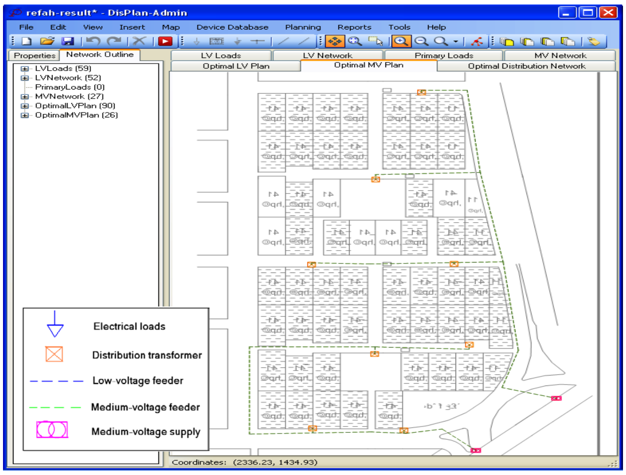

Fig. 2. Optimal MV network of the urban area with transformer utilization factor of 0.75

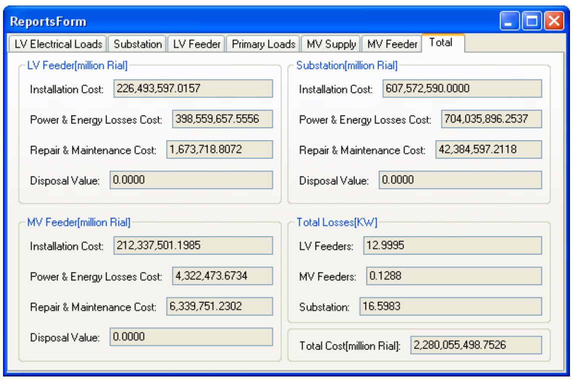

Fig. 3. Different parts of cost and power loss in optimal-planned distribution network with utilization factor of 0.75

It is seen in Fig. 4 that the investment cost of the LV network has lower values in the plans with lower values of transformer utilization factor. It seems obviously true because whenever the transformer utilization factor decreases the number if transformer in the plan increases and then, the length of LV network reduces; which results in reduction of LV investment cost.

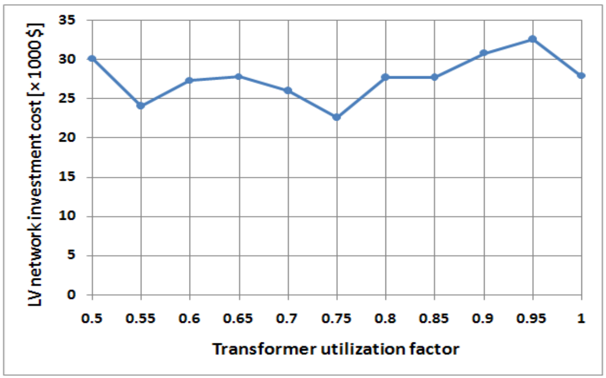

Fig. 4. Investment variation of LV network regarding different values of transformer utilization factor

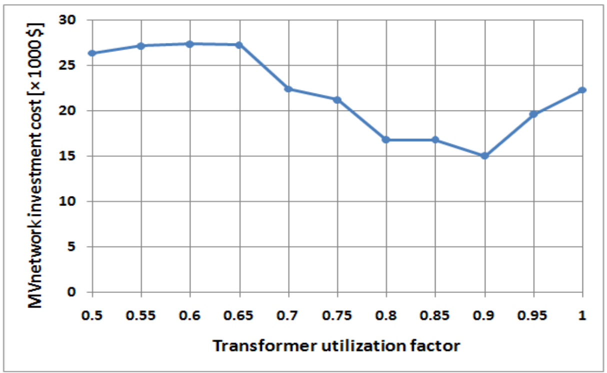

Fig. 5. Investment variation of MV network regarding different values of transformer utilization factor

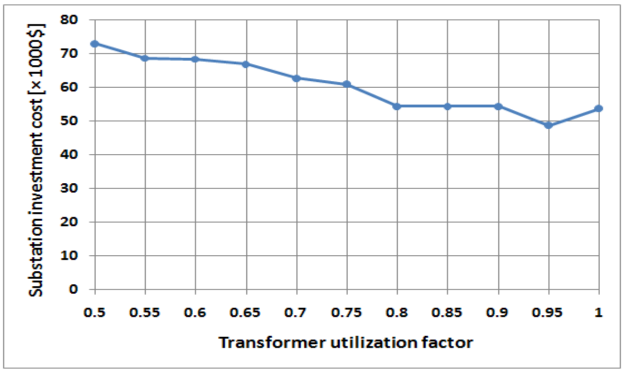

Fig. 6. Investment variation of distribution transformers regarding different values of transformer utilization factor

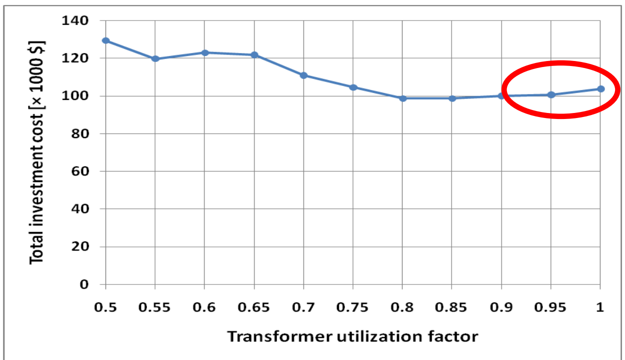

Fig. 7. Total investment of distribution network regarding different values of transformer utilization factor

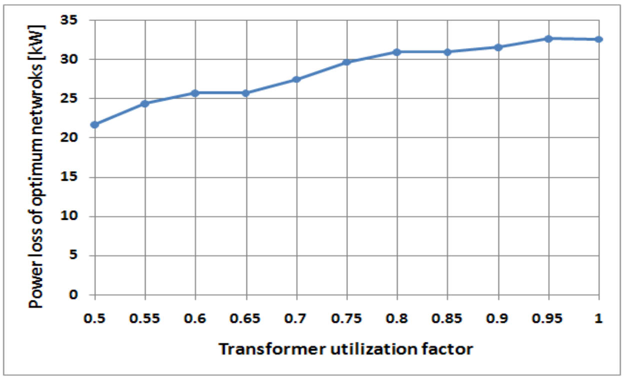

Fig. 8. Power loss variations of urban optimal networks regarding different values of transformer utilization factor

Reduction in transformer utilization factor and the increment of the transformer numbers are equivalent to the expansion of the MV network which means the increment of MV network investment. This fact is clearly shown in Fig. 5. In this case, the investment cost of distribution transformers also increases in comparison with the cases with larger utilization factors. Large utilization factors yields less number of transformers in the final plan and less investment costs requiring to install them (Fig. 6).

In this regard, the judgement about the optimum value of the transformer utilization factor from the viewpoint of investment costs can be accomplished through inspecting the total investment cost of the optimum planned networks (Fig. 7). In Fig. 7, it is seen that the minimum values of the total investment cost has been achieved for the transformer utilization factor range of 0.8 – 0.95 while their related power loss values (Fig. 8) also have almost the same values except 0.95. An interesting point is observed in Fig. 7 and that is the larger investment cost in the case of utilization factor 1.0 in comparison with lower values of utilization factor. It fairly illustrates that increasing the utilization factor of equipment is not necessarily equivalent to the reduction of the investment costs.

Industrial distribution network

In order to investigate the effect of transformer utilization factor on the investment and power loss values of an industrial distribution network, the second case study is studied. The network of the second case study relates to an industrial area in Tehran, Iran which its specifications are mentioned in Table 1. The procedure of the study tasks is similar to what is described in the previous section by using DisPlan. In this way, the results of the optimum plans with different values of transformer utilization factor for the industrial case study are depicted in Figs. 9 – 13.

As can be seen in Figs. 9-13, the total trend of the graphs is similar to the urban case studies. In this case, the important point about the optimum value of the transformer utilization factor is the preference of the 0.95 with respect to 1.0, because the power loss of the network has less value in the case of 0.95 comparing to the case of 1.0 despite of the same investment cost for both of the cases.

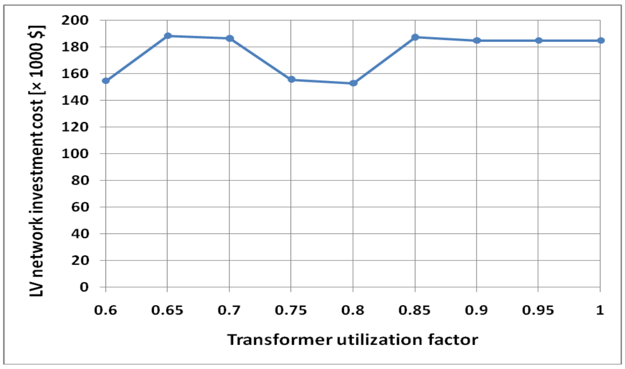

Fig. 9. Investment variation of LV industrial network regarding different values of transformer utilization factor

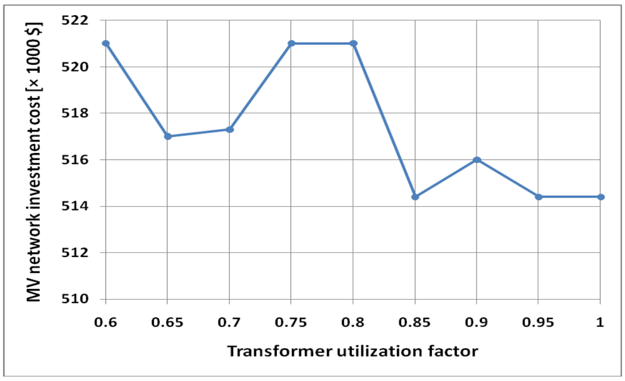

Fig. 10. Investment variation of MV industrial network regarding different values of transformer utilization factor

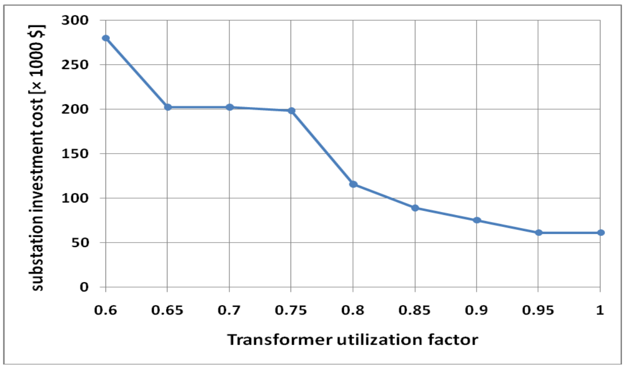

Fig. 11. Investment variation of distribution transformers in industrial network regarding different values of transformer utilization factor

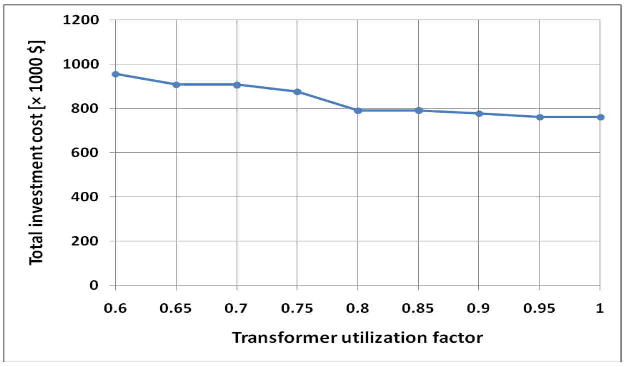

Fig. 12. Total investment of industrial distribution network regarding different values of transformer utilization factor

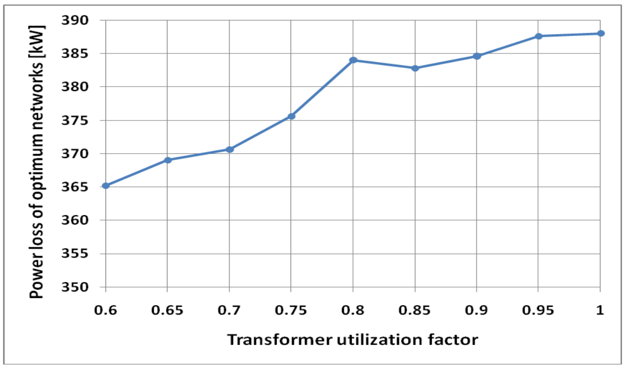

Fig. 13. Power loss variations of industrial optimal networks regarding different values of transformer utilization factor

CONCLUSION

In this paper, two main types of distribution networks namely, urban distribution network and industrial distribution network were studied from the viewpoint of the transformer utilization factor. Several plans were provided for different values of the transformer utilization factor and the economical and technical aspects of the plans were investigated. The results were shown that the higher values of the transformer utilization factor are not necessarily equivalent to lower values of investment costs and in some cases, increment of the transformer utilization factor may result the augmentation of the network investment costs as well as its power losses.

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