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Loss Reduction in Electrical Distribution Network by Increasing the Voltage Level to 22KV

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Abstract – In an electrical power system, there are energy losses in each stage of generation, transmission and distribution[1]. This has multiple effects, such as economical loss, environmental pollution, more chances of accidents due to melting of conductors, etc.It is the need of the hour to conserve energy. This is required to save the limited resources of fuel and to protect the environment.

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INTRODUCTION

Distribution networks were divided into primary distribution and secondary distribution in the past. However, the modern trend is to have only one distribution voltage level, 11 kV, which is derived from transmission substations through 132kV/11 kV or 110kV/11kV transformers.

Losses in the distribution of electricity cannot be eliminated, but can be minimized by proper planning of the distribution systems to ensure that power remain within limits. Some of the ways to reduce losses [2] include:

- Use of proper jointing techniques, and keeping the number of the joints to a minimum.
- Regular inspection of the connections, isolators, drop out fuses, LT switches, transformers, transformer bushing-stem, and other distribution equipment.
- Proper selection of conductor size, as well as the transformer in terms of efficiency, size and location. In particular, it is important to locate the distribution transformers at the load center and if possible keep the number to a minimum.
- Feeding heavy consumers directly from the feeders
- Maintain the network components and replace those that are deteriorating, worn out or faulty.
- Proper load management and load balancing
- Use of electronic meters which are accurate and tamper-proof.
- Improving power factor by adding shunt capacitors.

However, substantial improvements are not possible through the above methods. Here we are going to discuss a method to improve the loss situation substantially. Many of the electrical utilities had selected 6.6 kV and then converted into 11 kV as the secondary distribution voltage in the past. However, this involved substantial energy loss even at 11kV level and thereby revenue loss. We had taken up a study which revealed that the energy losses can be reduced substantially, by converting the voltage level to 22 kV, without substantially affecting the utility budget adversely, rather making a huge savings of money in the long run.

OBJECTIVE:

The objective of this paper is to device a work method to achieve the desired results for the reduction in distribution losses through adoption of distribution voltage level at 22 kV. The cost implication to the utility company is to be compared with the savings and a reasonable period of return of investment is to be achieved.

LIMITATIONS:

The major limitation for this project is the initial cost increases for the utility company.

The second limitation will be the compatibility of the new system to the existing system.

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The third limitation will be to select the geographical area where the new voltage level is to be implemented to avoid confusion during future maintenance/fault finding.

ADVANTAGES

Project is for operational voltage conversion from 6.6 kV & 11 kV to 22 kV, which leads to current reduction at the same load, thus improving the network efficiency by:

- allowing to increase the number of connected transformers (22 / 0.4 kV)
- decreasing the number of cables in corridors
- decreasing the load per ring
- increasing cable life
- increasing system reliability
- The operational conditions of 11 kV and 22 kV system voltages are similar

PROJECT PLANNING:

The following steps are involved at the project planning stage:

- Identifying the specified zone for new system.
- Designing the required proposals.
- Study rings load and modifying the existing ring load calculations based on the gathered information from the Geographical Information System (GIS) and the Single Line Diagrams (SLD).
- Preparing proposal area map and SLD for new voltage level.
- Listing out type and quantity of equipment.

PROJECT EXECUTION PROCEDURE:

- Budgeting for all the required equipment and cable quantities for coming voltage conversion projects.
- Procuring Transformers, Pocket Substations; Ring Main Units; Voltage Transformers etc.
- Preparing voltage conversion schedule in consultation with Utilities' Operation Department.
- Preparing weekly work program in co-ordination with Utility, Contractors and Private parties.
- Processing cable laying proposals & obtain No Objection Certificates (NOC)
- Installing cable for voltage conversion
- Supervision of Contracts works progress, wherever required.
- Avail Outages to carry out the conversion works.
- Replacement of existing Transformers/ Pocket substations
- Replacement of Voltage Transformers (VTs)
- Equipment Testing
- Cable Testing
- Commissioning.

PROJECT MONITORING AND EVALUATION:

The following steps are used for project monitoring and evaluation:

- Schedule the annual sequence of activities.
- Determine the minimum stock requirement of each item.
- Monitor and follow up the installation status.
- Control quality of works by adequate site supervision and monitoring.
- Check completion status of zone wise voltage conversion and prepare progress report.
- Monitor status of tenders (amount utilization) of Installation contracts, materiel procurement orders & follow up material Inspection status and receipt of materials as per order.

CASE STUDY

To demonstrate the reduction in loss by raising the voltage level, we have taken a case study of voltage conversion from 6.6 kV to 11 kV and then the same can be correlated to adopting the voltage level to 22 kV.

Details of a sample project undertaken in this field for converting a 6.6 kV system to 11kV systemis described in the following paragraphs.

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Under system voltage conversion from 6.6 kV to 11 kV, we had undertaken a project in one of the most famous electrical utilities in the Middle East. The total load transferred from 6.6 kV to 11 kV was 13,474 MVA. This involved replacement of more than 10,000 secondary distribution transformers along with related works.

Total cost of the project was AED 539 million

SAVINGS

Energy saved, calculated for a period of two years,

By Improving Distribution Network Efficiency – 1020.98 million kWH

Through Voltage Conversion from 6.6 kV to 11 kV

Cost of energy saved by Improving Distribution Network

Efficiency through Voltage Conversion from 6.6 KV to 11 KV: AED 286 million

The power loss savings resulted in avoiding the need to install two substations of 132/11 kV. Their cost is about AED 120 million, in addition to avoiding installation of generating stations of AED 455 million.

The project saves huge quantity of cables that are required for new load connections, since the cables became able to carry additional loads by 66% on 11 kV.

Due to the electricity losses reduction, the required supply feeders are reduced. The saved feeders were 77 Nos., which equals to AED 63.3 million.

Apart from the above, the following environmental benefits also have been achieved by this project.

It is predicted that the carbon dioxide will result in an average global temperature increase of 1.4-5.8°C by 2100. This is relative to a temperature increase of only 0.6°C in the last century. Even smaller rises in temperature may cause substantial climatic changes, such as changes to cloud cover, precipitation, wind patterns, the duration of seasons, and increase sea water level

The environmental benefits from the energy conservation projects are assessed as follows:

Due to the losses reduction, about 743 thousand tons of CO_2 equivalents have been saved in two years.

Since it is anticipated a rapid growth in electrical demand during the coming 10 years, this will lead to rapid growth in the distribution system as well. Therefore, conversion of the existing 6.6 kV system to 11 kV and install new distribution system with 11 kV shall maximize the electricity savings.

APPLYING THE 22KV CONCEPT IN THE CASE STUDY:

In the above case study we are bringing 22kV instead of 11kV. As we know, if the voltage is doubled, the current will be half for the same power/energy. As the losses are computed using the formula $P = I^2 * R$, The reduction in current will affect the power/energy in square. In the above case study, the energy saving was observed as 1020.98 million kWH. This was for the 11kV system. If the system is 22kV, then 'I' will be replaced with 'I/2'.

Hence, for 11kV system, saving in energy losses is = Energy loss in 6.6kV system – Energy loss in 11 kV system $= I^2RT - (I(6.6/11))^2RT$

$$= I^2RT\,(1\text{-}6.6/11)^2 = 0.64 * I^2RT = 1020.98 * 10^9\ WH$$

$$I^2RT = 1020.98 * 10^9/0.64 = 1595.28 * 10^9 WH\text{----------}(1)$$

For 22kV system, savings in losses will be (Energy loss in 6.6kV system – Energy loss in 22 kV systems)

i.e. $I^2RT\,(1\text{-}6.6/22)^2 = 0.91 * I^2RT$

Replacing I^2RT from equation (1), the energy saving $= 0.91 * 1595.28 * 10^9 WH$

$= 1451.70 * 10^9$

$= 1451.70$ million units

The percentage of energy which can be saved by using 22kV system instead of 11kV is 1451.70/1020.98 = 142%

This will reflect in all the savings mentioned in the case study.

Comparison of profit and expenditure

The indicative costs are given in Table-1[3]

Table 1: Indicative Average Unit Costs and Equipment Ratings

Voltage Level	132 kV Grid Substations	Overhead Circuits	Underground Circuits	Distribution Substations
Unit Cost ($000) [a]				
11 kV	9,900	18	45	31
22 kV	10,900	20	56	36
33 kV	12,200	22	72	41
Average Rating (MVA) [b]				
11 kV	45	6	9	0.2
22 kV	80	12	18	0.2
33 kV	120	18	27	0.2

kV = kilovolt, MVA = megavolt-ampere.
[a] Unit costs (per circuit-km and per substation) are averages for typical sizes and include installation and commissioning (but exclude taxes and duties).
[b] Ratings are for installed capacity in the case of substations and thermal limits in case of circuits.

Increase in total cost of the project of new installations in 22 kV compared to 11 kV system will be110% to 124%.

For 11 kV, the cost of the project was AED 539 million

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For 22 kV, the increase in cost compared to 11 kV will be 539 * 0.24 = AED 129.36 million

For 11 kV, thecost of energy saved was AED 286 million

The energy saving for 22 kV compared to 11 kV will be 142%

Hence, increase in cost of energy saved for two years will be 286 * 0.42 = AED 120.12 million

Internal Rate of Return (IRR),considering the cost of

Energy savingper year will be AED 60.06 million

Payback period: 129.36 / 60.06 = 2 years and 2 months

CONCLUSION

It is evident from the above case study that the systems with 6.6 kV or 11 kV system voltagesif convertedto22 kV, substantial reduction in power loss can be achieved. The method used in the above case study can be applied to any utility with minor modifications. Similarly, transmission network losses also can be reduced by adopting higher voltages [4]. However, a proper study is to be conducted to select a suitable method to be adopted for the same.

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