Distribution Network Optimisation

In order to carry out an efficiency improvement programme in power sector, it is necessary to undertake a systematic investigation of the distribution system. The distribution systems, particularly in India, suffer from abnormally high level of losses. While countries like South Korea, Israel, Netherlands, Germany, and Finland have losses less than 5%, India has T&D losses in the range of 23-25%. Agriculture dominated States have T&D losses of even more than 40%. It demands DISCOMs to take effective steps towards solving this problem.

This is such an important issue that grab the attention of **Honourable President of India**, **Dr. A P J Abdul Kalam**, when talking to **The Tribune**, on August 24th, 2004, he said:

> …*India can save more than Rs 76,000 crore worth of investment by reducing the transmission and distribution (T & D) losses in the power sector. The T & D losses that stand at 40-50 per cent can be brought down to 15 per cent, the standard achieved by the developed countries*….
>
> …*The cost of reducing T&D losses will only be a small percentage of the cost of generating 19,000 MW of power, currently lost in excessive T&D*….

It's the time when an approach for designed network shall be adopted, which can provide an optimally designed system.

Present Scenario:

Indian power sector had covered a long distance since 1950, from total installed capacity 1712 MW to 101680.0 MW in 2001. Generation also increased from 5 billion units in 1950 to about 515 billion units today. Transmission lines have been raised from 2708 ckm in 1950 to more than 200,000. Almost 80% of villages have been electrified and more than 63% pump sets have also been energised. This all seems very promising and bright unless we face the dark side of the picture.

Even after a huge effort we are still far behind, when compared to developed or developing countries. For more then 20% Indians, electricity is still a dream. As table 1.1 shows there are States which have major problem regarding village electrification and household coverage.

State	Households without access
Assam	83%
Bihar	95%
Jharkhand	90%
Orissa	81%
U.P.	80%
West Bengal	80%

Table 1.1

The situation is not very optimistic even in other parts of the country. Last 50 years have seen a huge effort on the part of government and engineers for energising India. Yet this whole effort is wasted as a substantial part of the system is having leakage problem. The T&D losses are quite large in India compared to many other countries.

In 1980-81, such losses were nearly 20.6% which in years 1997-98, 1998-99 and 1999-2000 are reported to be 24.8%, 25% and 23.7% respectively. In India, most of the states provide un-metered supply to agriculture sector which is charged on the basis of the connected load. As the amount of electricity consumed by this sector is usually overestimated, actual T&D losses may be significantly higher than those reported.

This assumption is also supported by the fact that, the reforming states started reporting higher T&D losses after the restructuring of SEBs. T&D losses in Orissa before the restructuring of Orissa State Electricity Board (OSEB) (1994-95) were 24% and increased to a level of 50% after the unbundling of OSEB (1996-97). Other reforming states like Andhra Pradesh, Haryana and Rajasthan have also reported higher T&D losses after the start of reform process. This is mainly due to the realistic assessment of T&D losses in the power systems, which were earlier hidden as agricultural consumption.

As per reports of Power Trading Cooperation of India and State Electricity Regulatory Commission, in 2003-04, Sikkim had a highest, 78.27% T&D loss which was closely followed by Manipur (72.62%) & Mizoram (72.41%). More than 8 states were reported to be having losses above 60% including Bihar, J&K and Jharkhand. More than 14 states were reported to be having losses exceeding than 50%. For such states the situation can not be worse.

There are various reasons responsible for this poor performance. Few of them are:

- Improper HT/LT ratio
- Improper load management
- Long transmission lines
- Poor voltage profile
- Un-optimised use of resources
- Un-designed grid locations

Since independence, Indian power system is developed more by demand than by design. This approach has left numerous loop holes in the system. The overall performance of the system is far below the minimum desired level. High T&D losses are not the only issue that need urgent attention. To improve the performance of the system numerous other issues needed to be resolved. Major Problems of Indian power sector can be broadly classified under following heads:

- Excessive T&D Losses
- Obsolete Technology
- Frequent Interruption On Unplanned Network
- Poor Voltage Profile
- Low Operational Efficiency
- Low reliability of system
- Unoptimised investments

Now Distribution Network optimization process with proper system design approach shall be able to address all the following issues. This requirement can be stated in a single line as need statement of Indian power sector.

Need Statement:

"A purposefully designed and optimized healthy system, with maximum utilization of resources and capacity to support future growth"

<u>Distribution System Optimisation Approach</u>

For designing a network, that can address all necessary issues, it's necessary that the exact replica of the system is available for evaluation. This establishes the need of Detailed **Database** of the system. In case of unavailability of the data, which is the case with almost all Distribution companies, **Field Survey** is desired with utmost accuracy, collecting numerous details of the system. In brief, any Distribution Optimization Study can be classified in to four subparts:

- Database Management Exercise
- Technical Data Evaluation
- System Design & Recommendations For Improvement
- Evaluation and Justification of Recommendations

Hence any system optimisation or improvement study shall start taking data collection as Primary Step.

<u>Data Management Exercise</u>

Data management is the basic, and the most important step for any network optimization study. Results of any such study are entirely dependent on the accuracy of the data used. India is a developing country and so is the power system of India. The field situation keeps on changing from time to time and that make it highly desirable that any field data is verified before starting the actual optimization process. The data collection can be divided in to:

- Equipment data collection:

  Electrical system is a mixture of different technical equipments. There could be transformers of different rating, fuse, relays, over head lines, cables etc. all such equipments have their sub categories depending upon their capacity, voltage rating and place of use. Adding to complexity is the point that even the environment conditions can alter the actual performance and capacity of the equipment. Aging has its own effect on the overall performance of the equipment. Hence it is highly desirable to know the actual status of the equipments in the field.

  For making equipment database the technical details can be referred from the manufacture of the equipment. However deciding the present situation of the equipment is complicated. Various factors like age, loading, and environment of the system should be considered for this.

- Network data Collection

  Once the actual system equipment data is ready another most important issue is to know the actual connectivity of the system in the field. This is something which keeps on changing very frequently and may be changed in the middle of the study. Hence this is desirable to decide the basic system configuration in the field and then optimise the system, taking that as a base case.

- load Data Collection

  Load data collection shall include the details about:

  - Present loading conditions
  - Future Load Growth
  - Consumer details

  Although it is better to design the system keeping all these details in view and utilising them for the best performance, the actual data required may vary depending upon the desired results of the study.

<u>Technical Data Evaluation</u>

Once the accurate field, equipment and load details are available the second step is to extract the desired out put form such data. This data is a vast poll of information and to understand the actual system scenario should be evaluated technically and the actual system condition should be generated. This data can be useful, only, if the information can be extracted from it, in quantitative terms i.e. system loading conditions, % system losses etc.

There are various technical tools available for any such analysis. Results generated from these tools are more or less of same nature and can be interpreted in quantitative terms. Once such results are generated the actual system design starts. However we have not yet started the system design the process has already generated an important by-product, which is precise field connectivity.

<u>System Design & Recommendations for Improvement</u>

This is the basic desired output of the study. Once the technical evaluation of the system is done the quantitative reports should be generated. These reports shall include all major technical details about the system. Any good electrical system analysis tool can be useful for such reports. These reports or result sheets can be in form of:

1) Loading conditions of the system (Normal / Emergency)
2) Loading conditions of the equipments (quantitative and % of their capacity in normal and emergency situations).
3) Normal and emergency system configuration

4) System loading conditions on n^{th} year (Normal/Emergency)
"n" is the future year for which design is under consideration ex. 10^{th} year system configuration under normal and emergency loading conditions

Here it should be clear that the emergency scenario is one when one or more of the system components are not working properly. This could be a fault scenario or a grid failure. However considering a grids failure will make it extreme case in which case the investment will be gigantic. Hence a more realistic approach can be 11 KV feeder failures or 33 KV feeder failures (when system reliability is to be very high). However if the system in to be designed for a long period of time (say 10 years) and any new grid is expected in that duration, its optimised location can be decided during this stage only understanding its need in the future.

The output reports derived after technical evaluation of the data will consist of following informations:

- over loaded transformers , feeders , cables or conductors (present / future)
- over loaded transformers , feeders , cables or conductors (normal / emergency)
- in extreme cases over loaded grids
- unserved consumers or unserved load under emergency conditions

To have an optimised use of the resources this is desired that the resources are used to the max over their entire life period which will automatically increase the average of the system equipments and also increase the ROI of the system. Now a little bit of imagination will make it clear that the worst system scenario will be on n^{th} year (as the load will be increased, considering the load growth taken) under emergency scenario. Hence the present system design should be extracted from the future system design. This approach is called as **Top-Down Approach**

Keeping this in mind the system design shall be started for the worst case i.e. on emergency condition in n^{th} year. Design constraints can be decided by the utilities i.e. maximum loss or say situation that can be kept without taking any action. Utilities can decide the scenario that they don't care about and they can decide a limit after which the action shall be taken. This limit could be maximum unserved load or consumers or any special locations for example VVIP areas, hospitals etc.

It is understood that, different scenario in the study can be handled by more than one action; however there are few aspects that make few choices more desirable than the others. The systematic approaches towards the solution can priorities the choices. The solution approach can be:

- Primary step for any system optimisation is to see that the present system equipments are utilised to their best performance level and hence there should be no unused resources. To ensure this the load sharing shall be done among feeders and among transformers so as to ensure that the system is loaded equally.

- Load sharing among feeders and transformers will ensure that there is no unused resource left in the system, and if due to any reason some resource could not be used it can be kept in consideration for emergency scenarios.
- Once the present resources are fully utilised a Top-Down approach for the system design shall be adopted. This approach will ensure that the system is going through an optimised use of resources. A futuristic approach during design will help in more one way
    1) Early investment will help in reducing the present system load, adding to the average life of the system.
    2) Return on Investment on such investment will be higher as they will serve more then their future purpose.
    3) This approach can be helpful in reducing present problems (normal / emergency) of the system hence more than one purpose can be solved by such investments.

- Incase of transformer overloading there could be two instant solutions i.e. Replace the present Transformer or add another transformer and share the load. Both the situations can solve the problem but the desirable solution will actually depend on issues like additional capacity required, cost of erection of new transformer, life of transformer under consideration. However this should also start by solving the problem in n^{th} year and then coming back to present scenario.

- Now while solving the emergency conditions the basic point of consideration shall be "accepted level of non-performance of the system". This is a critical point as the investment is directly related to this.

Evaluation and Justification of Recommendations

Although all small details will be taken for study and every single aspect will be considered yet this should be clear that any study designed on paper will never be perfect. There will be issues which can not be foreseen and to resolve such issues final design suggestions shall be send to field validation. This field validation activity shall evaluate every single suggestion in the field and shall suggest any changes if required. There can be situation where best possible suggestions can not be adopted for example a suggested feeder can be crossing through some railway track or some area where new transformer is needed but can not be done because of space or any other field situation. All such suggestions shall be re-evaluated and solutions shall be suggested for new field restrictions.

These may not be all the issues to be considered for design. Every single system design study will have its own approach towards the problem. This will differ because the actual situations, field scenarios, funds available, geography of the system, future load and number of other things will be unique for any electrical system and hence the solution and the methodology will be entirely unique. But this approach will work as a base for the study and also provide a detailed platform for actual plan. If decide appropriately, matching to the needs of the utility and the system, any system design can be able to produce a healthy system. Now this shall be evaluated that how this approach will actually resolve the major problems of the sector, discussed earlier.

Evaluation of Distribution Network Optimisation Approach

This very normal approach can address most of the problems of Indian power sector as well as help in designing a healthy network. We have earlier discussed few major problems of Indian power sector, now we can evaluate the impact of such approach on overall system.

1) **Excessive T&D Losses:**

   As the new design system is balanced on the basis of load and is technically evaluated for its performance in field the overall length of the lines will be reduced. Lightly loaded lines will be sharing the load of heavy lines and where no such an arrangement is possible a new feeder will be suggested. Now another issue can be the actual performance may not match to the field performance of the equipments. To take care of such issues the design shall be done on 80-90 % of the actual capacity of the equipments, along with aging factor and environment situations and on peak load. As the voltage profile will be improved, in new configuration, this will also reduce the overall losses.

2) **Obsolete Technology:**

   Indian sub-transmission and distribution system lack from any technological advancement. Because of this any realistic evaluation of the problem is not possible. A detailed field survey, which is necessary for the distribution system project will provide a detailed data for all such problems. Although this will remain the issue to be addressed but the areas which have problem will be updated with higher tools and better approach. One such example can be using pre-paid meters and ABC cable for theft prone area.

3) **Frequent Interruption on Unplanned Network:**

   An unplanned network and uninformed management along with a fault create a perfect problem. In any such situation problems are informed late and are solved without planning. Now any optimisation system study is most useful for any such situation. This helps in more than one way:

   i) As soon as the fault is reported the possible reasons of the fault can be known, evaluating the weak links of that area, reported by system study.

   ii) Once the reason is known, size of the problem can be reduced by adopting a little change in the system configuration. As the system is designed for optimum use, this will reduce the affected area without having much field work which means a saving in time. Such new configuration can also be designed during the study by taking fault on different sections, one-by-one and designing system for such situations. This will reduce the overall un-served load during any fault condition. A detailed plan can always be available during any fault while will reduce pressure in critical hours.

iii) This approach will desire new system parameters to be added like feeders, transformers or lines which also help in reducing overall loading of the system, which in turn will reduce low voltage and loss problem of the system.

4) Poor Voltage Profile:

Poor voltage profile is the result of long lines and extra load. Both the problems can be addressed when we design the system for low losses and high contingency. Now the point of consideration is that while deciding regarding any action, effort should be made that it helps in solving more than one problem and should be useful in as many scenarios as possible. Like is case of putting up a new feeder it shall:

i) Share the load of heavily loaded feeder

ii) Reduce the overall lengths of the feeder by taking some distant placed loads.

iii) Should have capacity to help near by feeders, in case any fault occurs.

iv) Should be connected in to the system from a place from which it can be shared by maximum number of feeders.

5) Low Operational Efficiency:

A low operational here reminds of technical efficiency of the electrical system as well as managerial efficiency of the management system. To explain it let us take an example where a fault occurs in the field, and is reported to the electrical department and is resolved in x working hours, say 8 working hours. Now when the department receives the fault report it immediately concludes the reason of fault and the possible solution for it, but network is not able to support this solution say load switching from one feeder to another. Here management may have good operational efficiency but the system doesn't have that. In the reverse case may be the system is having the capacity but the management takes too long to judge the actual nature of the problem and possible solution.

In both the cases the consumer suffers as well as the utility looses its money. Now an updated and designed system along with properly informed management (which distribution system optimisation studies can provide) can help in improving the operational efficiency of the system.

6) **Low reliability of the system:**

   Reliability of the system is not a matter of attention for most of the utilities in India and the reason is not that they not put value to this issue. The actual reason is that utilities are most of the time struck in other problems, which left very less space for considering the reliability of the system. But all the exercise done to improve the system performance automatically improves the system reliability. As the system back up improves the ENS (energy not served) for the system reduces. Customer Average Interruption Frequency Index (CAIFI) and System Average Interruption Frequency Index (SAIFI) also get reduced once the fault duration is reduced due to optimised system.

7) **Unoptimised Investments:**

   With an expanding electrical demand and base every year huge investments are made in the system. These investments can be for the erecting of new system as well as improving the performance of the present system. But if the investments are made in such a manner that it can solve more than one problem the overall ROI (return on investment) of the system improves. As suggested earlier such studies shall force on finding combined solution to the problems, so that the investment is justified.

Hence, distribution network optimization can be taken as a basic and straight line approach towards a major problem. The idea is to make maximum use of present resources with futuristic approach. In a fast developing country, the major factor for optimised design is the system scenario after few years, otherwise any design will prove to be non-realistic and make the problem only worse. Few major utilities had already tried this approach in the past and were able to generate the results. One such utility is NDPL (New Delhi) who has done a tremendous job of reducing its losses from 44.86% in 2003-04 to 28 % in 2006. This shows that a serious effort can generate result even is the conditions are not that promising.

In nutshell, the time has come to work on to the system which is the core for any technical advancement and yet is lacking by it. For few reasons things may seem not that encouraging, this could be because of our slow system or old infrastructure, yet only the serious efforts will generate the results. We shall be sure that this will not be an easy effort and only one thing is surer that we can not avoid it for long.