ELECTRIC POWER DISTRIBUTION ASSET MANAGEMENT

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ABSTRACT

In this study, asset management strategies in power distribution systems are investigated chronologically based on short-term, mid-term and long-term time scales. New strategies and their interrelation and coincidence in different time scales are discussed. The central role of Information Technologies (IT) in asset management is emphasized with supportive examples.

I. INTRODUCTION

The restructuring and liberalization developments worldwide have increased the incentives for a cost effective and efficient use of available assets in generation, transmission and distribution segments of the electricity industry [1]. Essentially, asset management, which is the process of guiding the acquisition, use and disposal of assets to make the most of their future economic benefit and manage the related risks and costs over their entire life cycle, has gained more importance in naturally monopoly transmission and distribution sectors than before, like in the competitive generation industry.

This study categorizes the asset management strategies in power distribution sector, based on short-term, mid-term and long-term time scales. Short-term asset management is related with the operational issues of the network (Section 2), mid-term asset management is associated with the maintenance of system assets (Section 3), and long-term asset management is concerned with the strategical planning of distribution systems (Section 4).

II. SHORT-TERM ASSET MANAGEMENT (OPERATIONAL MANAGEMENT)

Main tasks of a Distribution Utility Enterprise (DUE) in short-term include the operation and control of the network ensuring the security and reliability of the power supply. Security of supply is the ability of the network to meet customer demand without suffering an interruption in the first instance, and secondly, where an interruption develops it is the ability to restore power more quickly via alternative supply options. The number of customer interruptions and customer minutes lost per connected customer are common measurements of the reliability assessment today. Monitoring and tracking the asset conditions in real-time, and restoration of the faults that result in supply interruption for some customers due to the radial topology of the distribution systems (such as short circuit on the distribution feeder) are among the critical tasks of DUEs in the context of providing reliable power supply. Power system assets are monitored through the Supervisory Control and Data Acquisition (SCADA) systems which help system operators monitor and control the system in real-time. SCADA collects real-time data from Remote Terminal Units (RTUs) installed in substations and power plants, and distributed throughout the power system. It scans RTUs at a frequency of about two to five seconds. These data are transmitted to the system control center and stored in the Distribution Management System (DMS) real-time database. The DUE tracks and manages loads, maintains voltage profiles and maximizes the efficiency of the distribution system by the DMS.

Sub-transmission and distribution networks have a geographical reference. Geographic Information System (GIS), which stores spatial information about a utility's assets for representing the location and condition of assets including switches, relays, transformers, poles, cables, provides a variety of functions for asset management in all time scales. There are a large number of distribution cables in power distribution systems, most of which are under the ground and constitute a complicated cable network. Utilizing GIS, users can easily collect the information on the geographical distribution of cables based on GIS maps. This will provide useful reference for setting up of new facilities, provide necessary information on land use pattern for planning optimum expansion of network, and enable more systematic network operation control and maintenance. For example, the route information of underground cables facilitates the emergency maintenance crew who will dig to reach the faulty party of the cable that exposed to a short circuit. Customer information database can also be included in GIS database. Demand type, outage information and customer complaints are among the information that give important feedbacks to asset management decisions. Future developments of GIS technology may include SCADA processes technology.

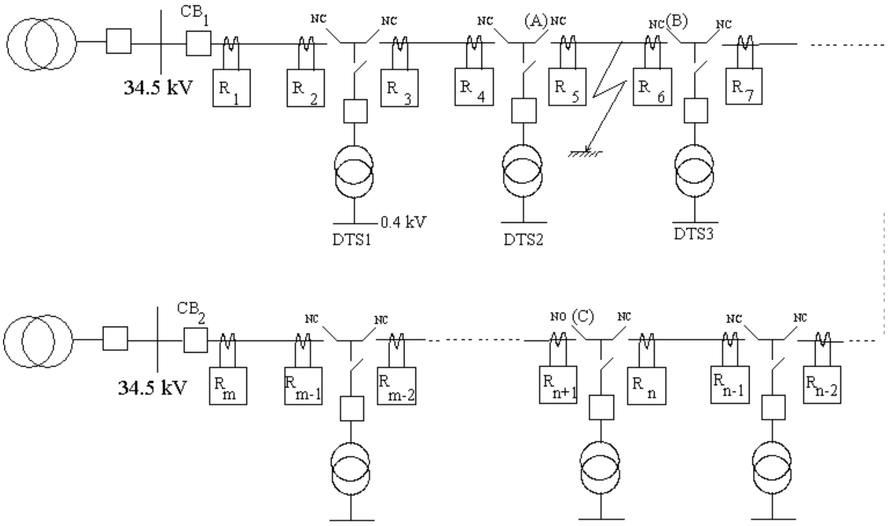

Fig. 1. FAS designed for distribution network of Istanbul-Turkey (TUDOSIS, TUBITAK-BILTEN)

II.1 FAULT RESTORATION

Automation Control System (ACS), which improves the continuity of supply in general, has long been stimulating the distribution engineers to consider it for location, isolation and restoration of the faults occurred in distribution systems. ACSs are indispensable to provide reliability particularly in metropolitan cities, where the distribution network is sophisticated due to heavily meshed underground cable network with lateral branches to adjacent loops.

The design of ACSs is usually specific to distribution system characteristics. The Feeder Automation System (FAS), which was designed specifically to improve the reliability of electricity distribution system of Istanbul, the biggest metropolis in Turkey, is illustrated in Fig. 1 as an example [2]. The system operates as follows. In case of a fault at the indicated section of the feeder in the figure, the fault current is picked-up by the relays R1 to R5, but not by R6-Rn because of the radial system of operation. The circuit-breaker (CB1) at the beginning of the feeder opens and clears the fault at 1 second at most. Once the fault is located by the sophisticated algorithm of the hierarchical control subsystem of the FAS, then it can be isolated from the 34.5 kV substation provided that the disconnect switches at both ends of the line sections are remotely controllable. Using the same signal transmission medium, the disconnect switch at point A in Fig. 1 is ordered to open, which makes it possible to reclose the circuit breaker CB1 and thereby energizing the healthy portion of the system. In order to transfer the load behind the faulted section of the feeder, first the second part of the loop is de-energized by the opening of CB2, and disconnect switch B is ordered to open while C is ordered to close, and then CB2 is reclosed. (The load-break type of switches will also be useful in the transfer of the loads behind the fault without de-energizing the healthy part of the loop.) The whole operation can be done in less than a minute, reducing drastically the restoration time.

Distribution system topology should be appropriate to introduce such an ACS application. The configuration of the network assets and communication infrastructure for the FAS described above, are given in Fig. 2.

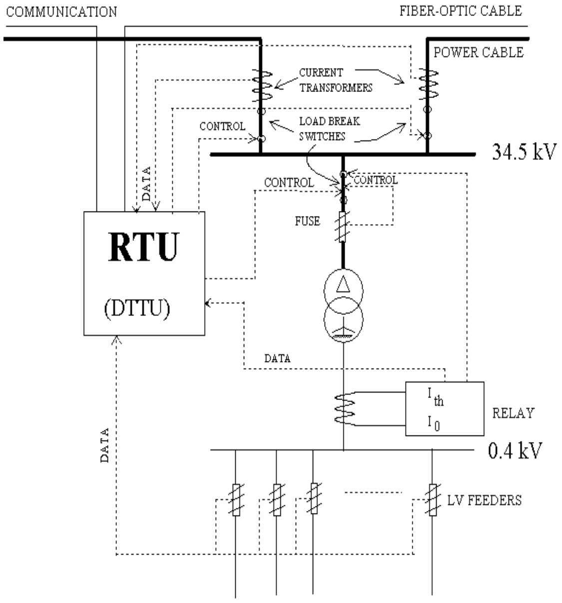

Fig. 2. Configuration and communication infrastructure of the 34.5 kV distribution transformer substation in Fig. 1 (TUDOSIS, TUBITAK-BILTEN)

III. MID-TERM ASSET MANAGEMENT (MAINTENANCE MANAGEMENT)

Mid-term asset management associates with the maintenance of assets. Since there is a cost involved in the maintenance (the cost of the service plus the cost of possibly interrupting load), many research works have been presented on maintenance scheduling optimisation, under the objective of providing a focused management framework, intended to ensure that the condition and performance of distribution assets continue to effectively meet the requirements of customers in the most economic manner. Maintenance scheduling entails a compromise between asset condition assessments at intervals sufficient to identify potential problems (and therefore prevent failures) and reduction of the duration and frequency of the planned outages.

III.1 OPTIMAL MAINTENANCE STRATEGY

Maintenance in a utility may be divided in three main categories: emergency (or corrective), preventive (or scheduled), and predictive. Emergency maintenance occurs after a fault, where the preventive and predictive maintenances intend to keep equipments and installation in proper working conditions, avoiding failures. Preventive maintenance can be divided in two categories further: Time-based Maintenance (TBM) and Condition-based Maintenance (CBM). TBM is performed at regular and scheduled intervals, loosely based on the service history of a component and/or the experience of service personnel (such as biannual oil inspection of transformers). CBM periodically determines the state of equipment deterioration, and maintains equipment when the condition falls below acceptable thresholds. (For example, maintenance of the circuit breakers is generally based on how many trips since last service.) Preventive maintenances do not explicitly consider the probability of failure and, more important, do not consider the consequences of failure. For example, two identical circuit breakers with the same condition may receive the same level of maintenance, even though one serves customers without an alternate supply, while the other serves customers that can be transferred to another feeder should an interruption occur [3]. Because of the radial system of operation, the reliability of an asset (such as circuit breaker) directly affects the reliability for the customers supplied through it. Preventive maintenance (or Reliability-centered Maintenance, RCM), which considers both the probability of equipment failure and the system impact should a failure occur, is an improvement over preventive maintenances. RCM integrates all of the other strategies and directs resources exactly to the critical points taking into account the functional importance of the device regarding service availability, as well as its condition.

Many numerical approaches have been developed in literature to prioritise distribution maintenance activities based on system reliability and cost-effectiveness [4]. Mathematical models, which represent the effects of maintenance on reliability, are needed in those approaches to find the optimal RCM strategy. The representation of the failure arising as a consequence of deterioration, identification of deterioration stages, the relation of maintenance on deterioration (and thereby component reliability), failure rate of an equipment as a function of parameters (such as maintenance history), identification of cost-effectiveness of each maintenance task, and cost of interrupting load for maintenance are among the information necessary to make such numerical analysis. Indeed, a comprehensive asset database, which consists of all necessary information based on periodic inspections, diagnostic tests, or other means of condition monitoring, is mandatory to develop an RCM strategy. This database can be included in existing IT applications such as GIS. In fact, since there is no unique product of system that covers all the facets of the asset management, the supporting IT applications have to be built on existing systems. This points out a need for applications and system integration over a robust IT infrastructure [5]. Therefore, favouring open standards that facilitate data and message exchanges among different utility systems and provide the framework for extensibility is quite important in the context of asset management in all time scales.

III.2 OPTIMAL OUTAGE PLAN

The optimal maintenance strategy should provide support for finding the optimal level of outsourcing of maintenance measures. Outage plan is the optimisation of voluntary disconnection, aiming to minimize interruptions for preventive maintenance. It deals with several databases on equipment and consumers information and past interruptions and may also include a load flow program to verify the possibility of transferring load. Although some services can be executed without disconnection, generally maintenance is executed on equipment without voltage, and due to the radial topology of distribution systems, this usually causes interruptions, which will be later computed for the continuity indices. Deployment of a portable diesel generator where alternative feeder is not available to transfer the load, employment of live line techniques, and application of FASs (especially for sophisticated networks) are among the strategies to avoid planned interruptions and to reduce unplanned interruptions.

IV. LONG-TERM ASSET MANAGEMENT (STRATEGICAL PLANNING)

Asset management in the long-term associates with identifying asset enhancement and development programmes required to meet target levels of service. The choice of a particular planning solution has traditionally been determined by performing network analysis considering the load growth and calculating the economic and financial implications associated with each possible solution. The solution that provides the minimum economic and financial impact would then be selected for implementation. In today’s demanding environment, issues such as distributed generation, reliability and quality of supply and environmental issues are now becoming as important as load growth and must also be included in the distribution planning activity.

Owing to the radial operation of power distribution networks, the reliability of distribution systems generally depends on the worst reliable equipment existing in the system. Therefore, decision-making techniques that applied to electricity distribution system planning should assess the conditions and performance of the system assets. In this context, IT applications plays a central role in strategical planning of distribution systems as the information base for decision making at all operational and strategical levels, as illustrated in Fig. 3. The degree of IT application should be based on the size of the system. For example, in the application of GIS, the distribution network data should be acquired in phases due to the large number of network entities and the large number of low voltage customers. In the first phase, data collection of sub-transmission network and sample low voltage system including consumers could be taken up. The sample low voltage network would be from high density, medium density and low-density pockets and covering different categories of consumers. This will serve the basis for determining the overall losses and improvements required in the entire low voltage network. In the subsequent phase, complete low voltage network could be taken up, if required.

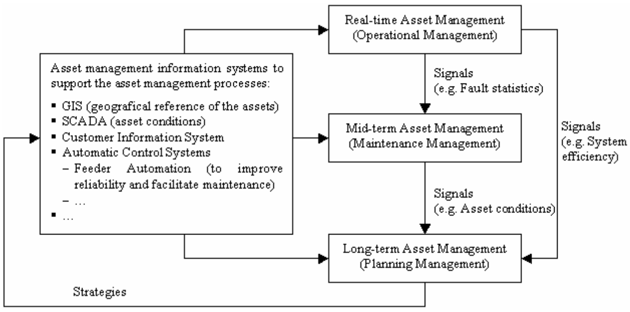

Fig. 3. Interrelation of asset management strategies through information systems

Distributed Generation (DG) encompasses any small-scale electricity generation technology that provides electric power at a site close to consumers. It is a good example that interprets the interrelation of long-term decisions and short-term strategies in power distribution sector, as discussed in the next section.

IV.1 DISTRIBUTED GENERATION

Today, with the restructuring of power sector and introducing competition, there is a scope worldwide to develop a generation business through adopting a more integrated perspective on distributed network asset management. The growing interest in DG is strengthened by the availability of more efficient and modular electric supply technologies. Indeed, the employment of DG could provide several benefits to almost all entities of power systems. Delaying or avoiding the need for capital expenditures to upgrade a congested sub-transmission network, improving the reliability by providing support to the local distribution network, reducing operation costs, and providing clean energy by renewable energy sources are among the attributes of DG for utilization in power distribution systems. On the other hand, DG is encountering various barriers that could hinder its connection to the utility's grid and the power market currently. These barriers can be categorized as technical, business practices, and regulatory barriers [6]. Business practices associate with contractual and procedural requirements for system operation and market participation. Regulatory barriers include matters of policy that usually fall within the jurisdiction of state utility regulatory commissions (such as FERC of USA). These barriers arise from or are governed by statutes, policies, tariffs, and regulatory filings by utilities, which are approved by the regulatory authority. Technical challenges associated with the utilization of DG in distribution systems are divided into three categories: i) DG interfaces with distribution systems, ii) operation and control, iii) planning and design. The existing distribution system SCADA/DMS infrastructure should be enhanced with new functions in order to realize the real-time monitoring and control of the distribution system in order to ensure the security of distribution system operation under the increased number of DG units [6].

V. CONCLUSION

Asset management strategies based on three different time scales (short-, mid-, and long-term) are quite interrelated and coincident in power distribution sector, and therefore, their coordination is very important in today's demanding environment. IT applications play a central role in the asset management of a distribution utility in all time scales. Therefore, integration of IT applications over a robust infrastructure is indispensable for the optimal asset management. The availability of efficient and modular electric supply technologies strengthens the interest in DG and makes it an important consideration in long-term planning decisions, introducing new operational issues.

REFERENCES

1. M. Shahidehpour, R. Ferrero, "Chronological Strategies for Power System Asset Management," accepted for IEEE Power & Energy, Vol. 3, Issue 3, May 2005.
2. N. Ozay, A. N. Guven, A. Buyuksemerci, M. Fettahlioglu, "Design and Implementation of a Feeder Automation System for Distribution Networks," IEEE Power Tech'99 Conference, Aug 1999.
3. Fangxing Li, Richard E. Brown, "A Cost-Effective Approach of Prioritising Distribution Maintenance Based on System Reliability," IEEE Transactions on Power Delivery, Vol. 19, No. 1, Jan 2004.
4. J. Endrenyi et al., "The Present Status of Maintenance Strategies and the Impact of Maintenance on Reliability," IEEE Transactions on Power Systems, Vol. 16, No. 4, Nov 2001
5. T. Kostic, "Asset Management in Electrical Utilities: How Many Facets it Actually Has," IEEE Power Engineering Society General Meeting, July 2003.
6. M. Shahidehpour and Y. Wang, Communication and Control of Electric Power Systems, John Wiley and Sons, June 2003.