THE DEVELOPMENT OF DISTRIBUTION systems poses new challenges in the changing world, where levels of electrification need to be increased and electricity served reliably for sustainable economic and social development. Technological development and adequate regulations are required at the distribution level to respond to new energy challenges and the restructured environment. The need for a change in the way distribution systems are designed, planned, operated, and managed is a must for both developed and developing countries. All changes should ultimately ensure optimal and economic service to the consumers of electricity. While the basic parameters remain the same, the challenges to be met are substantially different.

This issue aims to show how this is dealt with in developed countries like the United States and the United Kingdom, in the fastest developing countries such as China and India, and in Latin America, the pioneer in power sector deregulation. The new concept of microgrids and the latest related research and development are covered in a separate article. The six articles in this issue review the past, present, and the future of the distribution systems.

The articles provide a glimpse into the exciting developments, challenges, and opportunities in the distribution systems of the 21st century.

The Past
Toward the end of the 19th century, dc distribution systems came into existence. However, recognizing the value of electric energy and the need for development of economic sources of electricity, our forefathers wisely replaced dc with ac during the early part of the 20th century. Subsequently, the ac systems grew enormously, making the development of the electric power system the greatest achievement of the century. Unfortunately, several persistent problems with distribution systems lingered for many decades. They did not receive the attention they deserved under the regulated environment when compared to generation and transmission. Very little attention was paid to the planning, design, operation, and management of these nonbulk systems. Performance optimization for efficiency, regulation, and other measures was not adequately addressed.

The Present
Perhaps the manner in which the business was regulated contributed to the current state of affairs in many distribution systems worldwide. If we analyze just the efficiency as one issue, many electric companies in a number of countries, both public and private, are still experiencing very high system losses, in the range of 30–50%. In addition, voltage regulation at the customer premises sometimes is excessively poor, placing undue stress on the loads at this end. In many developing countries this has an added complex socio-economic dimension: the need to have access to affordable electricity supply as a basic human need.

The cumulative benign neglect of the past is frequently coming home to roost in the form of aging distribution infrastructure that is still operational though it has far exceeded its intended life span. Its ability to survive natural disasters has become more of chance than design. For example, there are underground cables and overhead poles installed in 1930s still in service. Aging conductors of inadequate capacity (from the current demand point of view) are still supplying power, though with poor performance. It is amazing that these major components have survived thus far. The conservativeness of the design and operation may have prolonged their life expectancy. The question naturally arises: How long will they survive and at what cost to the utilities, or for that matter, to the world citizenry?

The Future
The outlook for the future is not all doom and gloom. Many positive changes have been rapidly occurring during the last decade, perhaps due to the deregulation (or re-regulation) of the industry. We have become increasingly dependent on electricity being a basic necessity for existence.
It is also the backbone for future economic development if we are committed to improving the quality of life for all mankind. We have witnessed electric power systems becoming larger and more complex in the last 60 years due to the unprecedented growth in the demand for electricity coupled with population growth and higher standards demanded by society. Distribution systems are no exception. Globally, these lower voltage power systems are facing intensive competition with tremendous challenges to cover the ground of past neglect and for delivering cost-effective electric supply while meeting ever-increasing customer expectations. Globalization is yet another factor to keep in mind when designing, planning, and operating distribution systems of the future.

**New Developments**

On the technology front, the penetration of new technologies and materials for efficient distribution systems, including distributed generation, and the availability of efficient computation and analysis tools provided the encouragement and the impetus to make the distribution systems of the future more efficient and effective. As a result, the monitoring, control, protection, and automation of these systems in real time are becoming a reality. Demand management at the consumer level to match the availability of supplies to lower costs would be a distinct possibility in such an environment. The distribution community should seize this opportunity to make these lower-voltage systems safer, more secure, and more reliable while meeting the ever-increasing demand with the highest possible performance. The asset management intended to prolong the life of existing equipment while integrating the new technologies is receiving increased attention. The overall risk management of resources, including finances, will assist the utilities to utilize them wisely and effectively. Thus, many optimistic trends are emerging as we start our journey into the 21st century.

**table 1. Clarifications on terminologies.**

<table>
<thead>
<tr>
<th>Terminology</th>
<th>Equivalent Terminology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution systems</td>
<td>Distribution networks</td>
</tr>
<tr>
<td>Primary distribution</td>
<td>Medium voltage, high tension</td>
</tr>
<tr>
<td>Secondary distribution</td>
<td>Low voltage, low tension</td>
</tr>
<tr>
<td>Consumption: kWh</td>
<td>Units</td>
</tr>
<tr>
<td>Topology: Radial tree structure</td>
<td>Radial with primary and/or secondary selective</td>
</tr>
<tr>
<td>Primary feeder protection:</td>
<td>Circuit breakers</td>
</tr>
<tr>
<td>reclosers, fuses</td>
<td></td>
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</tbody>
</table>

**In This Issue**

Please take time to read the six thought-provoking articles to appreciate the stimulating developments happening in many different but related directions. Though these articles have different flavors, they have a common theme that the planned developments are absolutely essential if the distribution systems of the future are to serve the needs of the society. The summary and salient contributions of each of these articles are captured below for the benefit of the readers.

Terminologies adopted in many parts of the world are different but mean the same thing. Sometimes they can be confusing. We have made an effort to clarify some of the key phrases that mean the same (Table 1).

The first article, “Many States of Distribution,” by James D. Bouford and Cheryl A. Warren, provides a brief synopsis of the prevalent distribution systems in use today. The article starts with an interesting review of 125 years of history. In this process, the authors cover the distribution voltage development and the radial nature of the topology very clearly and effectively. Readers are encouraged to pay attention to the unique nature of topology adopted in North America as opposed to the structures that are in vogue in other parts of the world such as China and India. This article also describes the changes that occurred due to re-regulation of the electric power industry. To quote, “Shifting from the cost of service (COS) model for rate making, utilized for as long as regulation has been in existence, to long-term rate plans that include cost-sharing mechanisms between utilities and customers has certainly led to a different infrastructure investment pattern for utilities.” This powerful statement is perhaps true for all countries in the world that are experiencing deregulation. The article concludes with the role of new technologies. In particular, the authors make a convincing case for distribution automation, communications, and distributed generation. To quote, “Distributed generation, communicating with and controlling customer equipment, circuit devices operating on their own “intelligence,” and instantaneous data availability for any device or operating condition will change our distribution systems, and the way we run them, in ways that can only be imagined. The times are changing, and exciting times they are.”

The article “Chinese Growing Pains,” by Jin Zhong, Chengshan Wang, and Yiping Wang, describes the sustained high economic growth in the past two decades in the urban areas. Their fundamental tenet for a rapidly developing country is underscored in the statement that “the high-speed economic development drives the increasing consumption of electricity.” They also stress that while “the installed generation capacity has increased by eight times, the efforts and investment on transmission and distribution networks are less than that in generation systems.” They recognize that “the transmission and distribution systems are the bottlenecks of power transfer while admitting that although the distribution systems have been reconstructed in the past decades, the reliability, power quality, and distribution automation
levels are still lower than developed countries.” Finally they make a case for more investments in the distribution systems since “the grid companies have scheduled a big investment in high-voltage transmission systems in the coming five years, but the situation of distribution systems has not improved.”

“Powering Progress,” by Shrikrishna A. Khaparde and Anil Kumar Sardana, begins by stating that “India is in a state of flux as far as the power sector is concerned. The distribution sector, which was not well attended to, is now in focus. The Ministry of Power has been more active since 2001 and has initiated many new schemes. Though the progress curve has a positive slope, a recent review of schemes shows a gap between projected and desired goals. The tariff rationalization and reduction in losses are key issues. Proper policies implemented by the regulators can handle these issues. New technologies like IT applications and AMR will play an important role in managing the future needs of the distribution sector. The private sector participation has yielded excellent results.”

The authors conclude that the “next five years are critical and the Indian power sector will be watched closely by all global and domestic players wishing to have a piece of the pie in the great imminent opportunity that the sector beholds.” Though this is not addressed in the article, when the Electricity Act of 1948 was adopted, regulation meant achieving the spread of electricity to urban and semi-urban areas to ensure abundant supply of electricity at the cheapest cost and quasi-commercial operation of utilities. This is perhaps to limit the profit at a reasonable level and also make it attractive for investment.

Several key differences could be discerned from the first three articles. These include: different voltage standards, topological arrangements, average length of primary and secondary lines, losses, and voltage regulation. The average customer in developed countries consumes about five to ten times more electricity (about 5–10 MWh) than in developing countries (about 0.5–1 MWh).

One can also clearly observe that the focus of the future is on urban systems in both China and India where tremendous economic growth is happening. Nonetheless, the electrification of suburban areas or villages is also receiving serious attention. In this respect, China is far ahead of India in both electricity usage and economic development. One of the main concerns in these developments is whether proper attention is being paid to serious environmental issues in preserving the ecology for generations to come.

The fourth article, by Hugh Rudnick, Alejandro Arnaud, Sebastian Mocarquer, and Efrain Voscoboinik, called “Stimulating Efficient Distribution,” focuses on the price regulation schemes in most of the Latin American countries. Each country’s situation is described very clearly through proper comparisons. The authors emphasize that a growing challenge in the restructuring of the electrical sector, where competition is introduced in the generation area, is to achieve equivalent efficiencies in the electrical distribution service, an activity that develops in a monopolistic environment. To quote the article, “Latin America has had an experience of over 20 years of applying incentive price regulation to its distribution companies. The Latin America experience of incentive regulation for distribution companies has resulted in a sustained evidence of efficiency, through clear incentives for cost reductions, and attraction to investors, given adequate returns to investment capital.”

The authors also add, “There are no major implications in the application of regulatory reforms in network development technology, except for specific cases such as commercial loss reduction. In fact, regulation signals for loss reduction have motivated distributors to adopt distribution models of the U.S. type even in countries with European distribution, since they have proved to be efficient against energy theft.” The last point is a very serious issue with many other developing countries that must be corrected by improving system efficiency and through effective conservation programs.

“Taking an Active Approach,” by Predrag Djapic, Charlotte Ramsay, Danny Pudjianto, Goran Strbac, Joseph Mutale, Nick Jenkins, and Ron Allan, looks into the future of distribution networks in Europe and makes a strong case for distributed generation implied to be both renewable and sustainable. Their contribution is best summarized as the following:

“Deployment of distributed generation (DG) into the existing passive distribution networks is reaching a critical point whereby it can no longer be installed in the typical ‘fit and forget’ fashion without impacting network operation and stability. This article draws on recent advances to explore active management technologies, developing regulatory arrangements for network operation, and new commercial opportunities emerging from the low-carbon climate change agenda. It explores the changing role of the distribution system operator in response to increasing penetration of distributed generation and identifies the transitions currently taking place in the United Kingdom toward integration of distributed generation that has wider implications for extrapolation across Europe.”

A general observation on distributed generation: Electric utilities in OECD countries have indicated that up to 10–15% of electricity generation from dispersed, intermittent sources of generation could be managed easily but generation beyond that share could affect system reliability.
Finally, the article “Microgrids,” by Nikos Hatziargyriou, Hiroshi Asano, Reza Iravani, and Chris Marnay, describes on-going research, design, and development of experimental projects in four countries. They conclude the status of these projects as follows:

“Microgrids are a future power system configuration providing clear economic and environmental benefits with respect to expansion planning and efficient operation of modern power systems. It is clear that development concepts of microgrids require considerable efforts in relation to resolving numerous economic, commercial, and technical challenges. Extensive R&D efforts are therefore in progress, especially in Europe, the United States, Japan, and Canada in order to provide efficient solutions and to demonstrate microgrid operation concepts in laboratories and in pilot installations. Close cooperation and exchange of information among these activities in the form of international symposia has proven highly beneficial for the advancement of the relevant research. Coordinated, joint R&D efforts are expected to provide further mutual benefits for the research parties involved.”

**Epilogue**

Distribution systems require regular upgrading and modernization to continue providing quality service to consumers. Nevertheless, in countries where the demand for electricity has reached a plateau, the systems suffer from aging infrastructure and reliability issues. In countries where the power demand is high, the extension of an upgraded electricity infrastructure in urban areas is becoming a necessity that will require investment. Reliability of supply in many cases is compounded by the shortage in power supply and inadequate power delivery systems. The need to stimulate efficiency in investment and operation is a must. The tools to evolve the solutions to the problems and technology for implementation are available. The cost of implementation would, however, be substantial. Therefore solutions have to be structured for phased implementation to ensure acceptability. Challenging and attractive times are faced by engineers contributing to these developments. For further insight into any of the topics covered in this issue, you are encouraged to go through the recent literature and the references cited at the end of each article.