

Studies on Morphological Characteristics and Typical Power Supply Modes of Distribution Networks for New-Type Towns

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Abstract. With the constructions of new-type towns, power demand in the towns grows constantly. In this paper, we have analyzed new features of towns and power utilizations in the new circumstances, and promoted morphological characteristics of distribution networks for new-type towns. We have stated several indicators for the measurement of distribution networks for new-type towns as well as the influencing factors of optimizing operation for the networks. We have analyzed the quantized influences of network structures, equipment levels, automation levels, distributed powers and reactive compensations on the operation of distribution networks, and propose technical measures for the existing problems. With considerations of the influencing factors of power demands in new-type towns, we have computed the weight of each factor through Interpretative Structural Models (ISM) and Analytic Hierarchy Process (AHP), and concluded three power supply modes of the *Industry-Oriented*, the *Commerce-Oriented* and the *Synthetic*. Taking the Industry oriented power supply mode as an example, we have analyzed the requirements of networks, as well as the construction target, contents and configurations for the mode.

Introduction

Urbanization is a natural historical process in which the non-agricultural industries and populations concentrate in urban areas with the development of industrializations. It is an objective tendency of human society development and an important sign of modernization for the country. As indicated in the *state plan for new-type towns*, promoting green development of towns, increasing intelligent levels and enhancing historical cultural charms are the developing tendency of new type towns. The new-type towns incorporates the idea of ecological civilizations and share the features of green environment, green economy, green society, green humanity and green consumptions, thus will promote clean, environmental and intelligent constructions of distribution networks.

Due to the differences in energy distribution, economic developing levels, load density and environmental factors, China has adopted distribution network structure different from those in other countries. China uses mainly the radial structure, and the feeders are fewer and unreasonable. Although, the "hand in hand" structure have used in certain areas of China, the feeders with insufficient capacity are reluctant to transfer load when malfunctions happen. With the growing of network loads as well as the development of distributed generators, traditional distribution networks in towns cannot afford the growth of power consumption in the process of new urbanizations as well as the influence of distributed generators with high permeability on distribution networks.

The construction of distribution networks in new-type towns targets at serving the development of the towns. In this paper, we first analyze the characteristics of new-type towns as well as the new power utilizing characters in the process of new urbanizations, then we promote the morphological characteristics of distribution networks in new-type towns and analyze the requirements of new-type towns in energy quality, power supply reliability, network structure and economical efficiency. We construct influencing factor models for distribution networks in new-type towns with ISM, and compute the weight of each factor through the method of AHP. Then, we classify the power supply

modes of new-type towns through example analysis, and detail the construction targets, contents and mode configurations of power supply modes with the industry oriented power supply mode as an example.

Characteristics and power utilizing features of new-type towns

As thousands of towns are scattered in the wide areas of China, they share significant differences in energy structure, natural environment, industry structure, road traffic, architectural forms, population structures as well as other factors. In new-type towns, most people are occupied in non-agricultural industries and mainly accommodate in multistory buildings or townhouses with relatively high densities. With the transformation and upgrading of industrial structures, the intensive production mode is formed with the 2nd and 3rd industry as the main economical pillars. While green production and consumption act as the main economic lifestyle in towns, the resource-saving and environment friendly energy consumption mode are developed, thus making the living environment of towns more harmonic and livable.

The construction of new-type towns will promote growth in power demands, change power demand distributions and accelerate the development of power networks with intellectualization and collaboration. As larger amounts of distributed resources and energy storage systems are introduced into power distribution networks, the traditional passive networks will transform to be active. The electric charging facilities for electric vehicles require that distribution networks in certain areas provide relatively larger bearing and adapting capabilities. The ever growing demands of urban residents on power supply quality will promote the transformation of power supply enterprises from “the power tiger” to “the power waiter”, the emergence of new power retailers will largely increase the service level of the power industry. Technologies of sensors, communications, automatic control, and power resources are integrated in power systems, which achieve friendly interactivities between the power enterprises and the users in towns.

Morphological Characteristics of distribution networks in new-type towns

To meet the requirements of development for new-type towns, *the Energy Internet*, composed of intelligent power networks, distributed generators and so on, will bear and promote the third industrial revolution, thus produces more and more strict requirements on security, reliability and adaptability for power supplies. The distribution networks for new-type towns should provide features as follows:

Green and Eco-friendly. Clean resources, such as distributed generators and electric vehicles, share advantages of power-saving, emission reduction, security, flexibility and etc, and reduce the pressures of environment and peak load regulation in networks.

Robust and Intelligent. The new distribution networks share characteristics of information-driven, intellectualization and automation. The network structure is flexible and reliable, and the equipments is highly automatic, including automatic power distribution as well as requisition systems for power utilizing information which fully cover the lower-voltage side. Distributed generations in distribution networks are uniformly allocated to complementary supply of multiple kinds of energy. Internet technologies are adopted to achieve energy sharing in large areas.

Economical and Efficient. We should transform the developing mode of power networks, promote thoroughly the construction of intelligent energy-saving power networks, eliminate equipments of high energy consumption, optimizing the configuration ability of the power network, increase the utilization rate of equipments, generating power with efficiently utilization of new energy, lead the practice of scientific power utilizations and reduce the emission of carbon dioxide.

Friendly and Interactive. Technologies of information and Internet are widely used to achieve friendly interactions between power enterprises and users, such as guiding the users in a rational way of using the intelligent household appliances by making use of economic factors like Time-sharing voltages, thus supporting the generalization of Smart Communities and intelligent appliances.

Influencing factors and technical measures for optimal operation of distribution networks in new-type towns

The operation level of distribution networks reflects in two aspects of equipment operation and maintenance management. In the paper, we discuss exclusively the equipment and techniques of distribution networks.

Influencing factors on optimal operation of distribution networks in new-type towns. The grid structure, equipment level, new energy penetration, automation and reactive power compensation share different standards which directly or indirectly affect power quality, reliability, power supply capacity and economic efficiency.

The harmonics brought by distributed generation parallel connection produce voltage distortion in distribution networks^[1]. However, distributed generations do contribute to improve the reliability of power supply and to lower down energy loss. The paper of [2] argues that power supply reliability is improved through establishing double circuit power supply and multi-section multi-focal network structure, adding equipment capacity margin and switching capacity of liaison between the lines. The 4×6 grid structure have good transfer capability and high capacity utilization, which provides direction to plan and reform distribution network structures^[3]. Authors in paper [4] argues that grid structure together with equipment parameters determine the maximum power supply capability and are critical to satisfy the fast growth of load. Different connection modes of electric wire are compared in [5] according to equipment utilization, reliability, short circuit capacity, network losses and power quality, and argues that the way in which wires are connected affects equipment utilization and power supply reliability.

In this paper, we provide reviews on how the contents of grid construction affect the evaluation indexes with reference to the above achievement and on-site experience as well as the result of influence factors based on ISM. As the influence of construction contents on power grid evaluation indicators cannot be quantified, here only qualitative discussion are made, as is shown in Table 1.

Table1 The Influence of Construction Content on Evaluation Indicators for Distribution Network

Construction Content \ Evaluation	Grid Structure	Equipment	Automation	Distributed Generation	Reactive Power Compensation
Power Quality	little	little	medium	lack	major
Power Supply Reliability	major	medium	major	medium	little
Supply Capability	medium	major	little	medium	little
Economy	medium	medium	little	medium	medium

Note: major: decisive influence; medium: direct influence; little: indirect influence; lack: reverse direct influence

Technical measures for optimal operations of distribution network in new-type towns. There are more power quality problems in towns and rural areas, such as low voltages, insufficient reactive power. There are many technical measures, such as regulated capacity transformer, line-voltage regulator, reactive compensation device, harmonic suppression and so on. Meanwhile, low automation levels in certain areas results in insufficient support for on-load voltage regulation and automatic switching of reactive compensation device^[6, 7]. For town networks usually with longer distribution lines and scattered distribution, several technologies are adopted, such as live working fault treatment, feeder automation and distribution network production repair command platform, to shorten troubleshooting time and to improve power supply reliability^[8].

It is promoted in [9] that, in order to secure power supply in urban, distribution networks should be optimized by taking measures of adding interconnection substations and optimizing its distribution, increasing the ultimate capacity of substation and configuring section switches. That power supply capability should be improved with reasonably configurations of transformers on capacity and count, of

the high/low limits of load rate and of wires on sectional areas, especially the cooperation between distributed generations and the major power grid.

To achieve distribution network optimal operation, different technical measures are used for different targets to ensure safety and reliability of distribution networks, as is shown in Table 2.

Table 2 Technical Measures of Optimization Operation for Distribution Network

Targets of Distribution Network Optimal Operation	Level 1	Level 2	Technical Measures	
	Power Quality	Voltage Qualification Rate	Three-phase Unbalanced Rate	Reactive Compensation;
		Three-phase Unbalanced Rate		On-load Controllable Capacity Transformer;
		Voltage Flicker		Three-phase Unbalance Control ;
		Harmonic Distortion Rate		User Information Collection System;
	Power Supply Reliability	Power Supply Reliability Rate	Average Interruption Hours of Customer	Three Order Voltage Regulation;
		Average Interruption Hours of Customer		The Live Working Fault Treatment;
		Average Interruption Times of Customer		Expand Equipment Capacity Margin;
	Power Supply Capability	Load Transfer Capability	Load Capacity	Distribution Network Production Repair Command Platform;
		Load Capacity		Increasing Interconnection Substation Number;
Operating Economy	Equipment Utilization Rate	Line Loss Rate	Intellectualized Switchgear;	
	Line Loss Rate		Distributed Generation Parallel Connection;	

Classification of new-type towns and typical power supply modes

Many factors may influence the power demands in new-type towns. Information is deeply integrated among the factors, of which the weight differs among towns of different types. According to literature investigation and expert experience, we here demonstrate the influences of development of new-type towns on distribution networks in six aspects, namely energy, transportation, industrial structures, building forms, humanity and environment, each of which consists of multiple factors. For example, the factor *environment* consists of climate characteristics, weather, geological locations, etc. We construct a influencing factor model of new-type towns through ISM, and compute the influence of each factor on distribution networks in respect of grid structure, power quality, supply reliability, economical efficiency and new energy permeability. In this way, we have carried out multiple cases of power supply modes, typically *the industry-oriented*, *the commerce-oriented* and *the Synthetic*, which also includes *characteristic agriculture*, *tourism* and *others*). Here we take the *industry-oriented* case as an example to introduce the main influencing factors on grid structure of distribution networks, as is shown in Table 3.

For the new-type towns, we inherit the classification modes of power supply used in small towns, and emphasizes on four characteristics of *energy-saving*, *environment friendly*, *urban-rural coordination* and *feature significant*. The new-type town construction, together with the *beautiful rural construction* and the *smart city construction*, establishes the connections between urban and rural areas. According to *the State Plan for New-Type Towns, Typical Power Supply Modes in Small Towns, Typical Power Supply Modes for New Countryside ,Technical Guidance for Planning and*

Designing Distribution Networks, with respect to the data results achieved in an 863 project about active distribution networks, we classify the new-type towns into three classes, as is shown in Table 4.

Table 3 the main influencing factors of power grid network structure

Serial Number	Factors		Weight
1	S ₁₁	Clean Energy Permeability	0.108
2	S ₃₁	Per Capita GDP	0.124
3	S ₂₀	Industry Portion Structure	0.079
4	S ₂₈	Annual Power Sale	0.087
5	S ₂₂	New Energy Cars	0.063
6	S ₁₆	CCHP Storage Capacity	0.056

Table 4 Classification of Distribution Networks in New-Type Towns

Type	Sub-type	Annual income per rural resident	Power utilizing features	Constructing Goals		
				Power Supply Reliability	Voltage proficiency	Distributed generator permeability
Industry oriented	A1	>15000	Share of big industry in power sales >50%	99.93%	99.6%	0~25%
	B1	8000~15000		99.83%	98.8%	
	C1	<8000		99.72%	97.8%	
Commerce Oriented	A2	>15000	Share of industrial business & resident daylylife >40%, big industry <50%	99.93%	99.6%	
	B2	8000~15000		99.83%	98.8%	
	C2	<8000		99.72%	97.8%	
Sythetic	A3	>10000	Share of industrial business & resident daylylife >20%, big industry <50%	99.83%	98.8%	
	B3	6000~10000		99.72%	97.8%	
	C3	<6000		99.7%	97.0%	

Power supply mode for industry-oriented towns

Construction demands for distribution networks in industry-oriented towns. For distribution networks in industry-oriented towns, the network load is relatively concentrated and stable, and it requires high reliability of power supply and power quality. The line material is mainly overhead insulated lines supplemented by cables, which brings relatively small radius of power supply, flexible operation and small floor space. Electricity consumption information gathering systems, distribution automation systems and compensation devices are adopted to ensure the safety and reliability of distribution networks and satisfying the demands of resource processing towns.

The power resources of industry-oriented towns reside mainly in the power grid and distributed generators, of which the power supply mode is transformed to be an integration of the concentrated and decentralized modes. The network pattern is mainly looped networks and radiating structures with distributed generators, which provide flexible topology and reconstruction ability, thus distributed

generators with high permeability can be connected to the networks. Meanwhile, energy storage techniques, such as fuel batteries and UPS, should be developed in order to balance network load and optimize resource configuration. The power supply mode for industry-oriented towns satisfies the power demands of the towns, and provides the four morphological characteristics of distribution networks in new-type towns.

Power supply mode for industry-oriented towns. The power supply mode for industry-oriented towns could be classified into three kinds Mode A, Mode B and Mode C, each with different construction goals of supply reliability and voltage proficiency. Details are shown in Table 5.

Conclusion

In this paper, we have analyzed the morphological characteristics and developing tendency of distribution networks in new-type towns, and promoted three power supply modes, namely the industry-oriented, the commerce-oriented and the synthetic, which take in considerations the developing requirements of towns with different economic levels, environment and resource structures and thus ensure reasonable layout, reliable power supply, safety and economy of power distribution networks. The power supply modes of new-type towns can also help achieve line isolation, equipment intelligence, distribution automation and information-enhanced management, and is thus reproducible and diverse.

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Table 5 comparison of power supply modes in industry-oriented towns

Mode name				Industry-oriented mode			
Sub-mode name				Mode A1	Mode B1	Mode C1	
Annual Income (yuan)				≥ 15000	8000~15000	<8000	
Construction goals	Reliability			99.93%	99.83%	99.72%	
	Voltage precificencyu			99.6%	98.8%	97.8%	
	New energy permeability			0~25%			
Construction content	Clean resources(optional)			New energy(wind, photovoltaic, bioenergy, etc)			
	Electric vehicles						
	Smart community (intelligent appliance)						
	Energy storage devices(optional)			Fuel battery Electric heat/cold storage			
Mode configuration	Devi-ces	Line	Materials	Overhead Insulated Conductor/ Cable	Overhead Insulated Conductor/Cable	Overhead Insulated Conductor	
			Topology	Ring/Double Radiation	Double Radiation /Ring	Hand-in-hand/ Double Radiation	
			Segmentation devices	Pole Mounted Switch/ Ring Main Unit	Pole Mounted Switch	Pole Mounted Switch	
			Tapping devices	Load Switch/ Branch Cable/ Circuit Breaker			
	Distrib-ution transfor-mer	Public transfor-mer		Pole-type /box-type/distribu-tion station	Pole-type /box-type	Pole-type	
			User transfor-mer	distribution station	distribution station / Pole-type	distribution station / Pole-type	
	DG connection voltage level	220V, if DG capacity ≤ 8kw,					
		380V, if DG capacity in 8kW~400kW					
	System	Information system	10KV, if DG capacity in 400kW~6MW				
			DG monitor system/local DG regulation platform, if permeability > 5% or capacity ≥ 400kW				
		Production and Emergency Commanding platform, power utilization information gathering system,					
		Automation	Distribution automation (centralized)	Distribution automation(centra lized/on-site)	Distribution automation(on-si te)		
		Three-phase imbalance governance	Load commutation technology	-----			
Anti-islanding Measurement		Anti-islanding Device					
Reactive compensation		Automated Reactive Compensation Device					