THE ANALYSIS OF THE INFORMATION NEEDED FOR THE PLANNING OF ACTIVE DISTRIBUTION SYSTEM

Mingtian FAN
China EPRI
mtfan@epri.sgcc.com.cn

Zuping Zhang
China EPRI
zpzhang@epri.sgcc.com.cn

Tian Tian
State Grid EPRI, China
tiantian@sgepri.sgcc.com.cn

ABSTRACT

As the increasing application of ICT technology in power system, the information available is getting more and more, which has provided a firm foundation and possibility to the implementation of Active Distribution System (ADS). The key challenges at the ADS planning is how to integration with the optimization operation of DER（generation (DG, RES), Electricity Energy storage (EES) and interactive load）. The questions firstly is how to make use of the available information，secondly is which information is primary needed and have to be provided， and thirdly is how to coordinate the information resources. This paper presents an analysis of the information which is necessary to be used on the planning and optimization of passive distribution networks (PDNs)，including existing information system and available information, then analyses the differences between PDN and ADS, lastly, presents a simplified the future information model for ADS planning.

1. INTRODUCTION

As well know, for nearly a century distribution system had been regarded as the "far end" of the power system. Central generation was the most important part of the power system, and high voltage transmission and its protection and control was the key aspects that required finely honed engineering. Distribution system, while necessary, was a collection of local delivery systems of rather plain, standardized design, all built using MV and LV commodity equipment, and all engineered using unchallenging principles and rules that while comprehensive, the resulting performance was adequate but not all that it could have been: local distribution systems were designed to common engineering standards, not customer service and reliability targets. Thus local distribution was almost never optimized to local needs. During last 10 years because fossil energy crisis, more and more renewable energy source (RES) is increasingly access into PDN, but RES could not be consumed with great ratio under the existing technical condition of PDN[1].

According to the definition of CIGRE C6, ADS is the network which can actively control and management DER with flexible network topology and DER consists of three main parts, such as generations (DG, RES), Energy storage (EES) and interactive load[2]. As the increasing application of ICT technology in power system, the information available is getting more and more during planning and operation, which has provided a firm foundation and possibility to the implementation of ADS[3].

This paper presents an analysis of the information systems and available information which is necessary to be used on the planning and optimization of passive distribution networks (PDNs), then analyses the differences between PDN and ADS in detail especially in the information requirements, lastly presents a simplified the future information model for ADS planning.

2. ANALYSIS OF THE INFORMATION AVAILABLE

Existing information system and information

The planning and operation of distribution network consists of five main aspects: distribution planning, constructions, operation, marketing and equipment maintenance. Main information systems for each aspect are listed in table 1:

Table 1 Main Functions of Each Information System

System name	Main functions
DPMS	Distribution network planning
MMS	Supplies procurement, warehousing, distribution
CMS	Construction process management.
EMS	Online grid monitoring, control and analysis.
DMS	Online distribution network monitoring, control and analysis.
MBMS	Record electricity consumption information and billing, customer service management
PMS	Maintenance and management of the whole life cycle of the power equipment.
GIS	Geographic information management and display of power equipment

As sources of information, these information systems provide the following information:

Table 2 Information Provided

System name	Source of information
DPMS	Load forecasting results, system construction plans
MMS	Power supplies list
CMS	Contractors information, progress information for equipment construction
DMS	Distribution Network topology, some major equipment operating status
MBMS	Customer description, monthly electricity consumption
PMS	Detailed parameters of all equipment
GIS	Location information of all equipment

PDN planning information model

PDN planning in a large extent can be seen as a deterministic process optimization, in which the maximum load of the power users only need to be known during the planning stage because the system capacity could meet electricity demand at any moment.

PDN planning information model contains five types of objects: device object, equipment collection object, accounting object, parameter object, auxiliary object. All public properties of the object are code and name. Public properties of device object, equipment collection object, accounting object are location and description text. Public properties of device object, equipment collection object are accounting object coding, cost, construction time, put into operation time, estimated decommissioning time, forced outage rate and the current state.

Device objects are generator, main transformer, breaker, switcher, transmission line, bus, capacitor, electric reactor, distribution transformer, feeder line segment, node and load. The device object describes the physical attributes and operational characteristics of the equipment. For example, equipment collection object are power plants, substations, feeders. The accounting objects are power generation companies, transmission companies, power supply companies, independent accounting units.

Simplified device objects' properties in PDN planning are defined by IEC61970. The PDN planning information can be obtained from existing information systems, as shown in Table 3.

Table 3 device information sources

Information Category	Source
Load historical data	EMS、DMS、EBMS
New load information	EBMS
Network topology data	EMS、DMS
Device parameters	PMS
Load and device location data	GIS

3. ANALYSIS OF THE MAIN DIFFERENCE BETWEEN PDN AND ADS

The information for distribution system operation has its own uncertainty characteristics in nature because of lack of full measurement, full tele-signal and full remote control like the way in transmission system. The uncertainty of load and generation is traditionally covered by much larger capacity（or reserve margin） in system operation, though it is very uneconomical. With the help of ICT technology, Active Distribution System (ADS) is a better way to utilize DER with much more great effectiveness than passive distribution network（PDN）. Therefore, during ADS planning, load and generation curves may be divided three parts based on information system: certainty, small range uncertainty and large range uncertainty. The certainty and uncertainty information could be covered during the planning procedure about the capacity (transformers and lines) and different countermeasures, such as DSM, EES, EV and DG.

This section tries to define the differences between passive distribution network （PDN） and active distribution system (ADS）with five main classifications, such as technical standards, network configuration， simulation mode, management mode as well as operation mode, shown in table 3. Furthermore, the information requirement for ADS is analysed based on the five classifications in some more detail in order to provide information support for ADS planning and operation.

Table 3 Main differences between PDN and ADS

classifications	PDN	ADS
Technical Standards	Rigid	Changeable
Network Configuration	Fixed	Flexible
Simulation Mode	Average	Accurate
Management Mode	Centralized	di-centralized
Controlling Mode	Passive	Active

Based on the classifications of Table 3, many aspects affected by information availability for the five main classifications are shown in detail in the following Table 4 ~ 8.

Table 4 Technical Standards

Aspects	PDN	ADS
Operational Range	Fixed	Changeable
Feasible Criteria	Static	Dynamic
Reliability Target	Implicit	Explicit
Customized setting	Difficulty	Easy

Many aspects for technical standards have been shown in Table 4, from which we know if much more information is available during the ADS planning and operation, then technical standards should be with many new feature, such as changeable operational range, explicit reliability target and dynamic feasible criteria as well as easier customized setting.

Table 5 Network Configuration

	PDN	ADS
Power Source	without	With
Operation mode	Radial	Mesh
Load direction	Unidirectional	Bidirectional
Islanding operation	Non-optional	Optional
Switching unit	Un-adjustable	Adjustable
Storage	Un-controllable	Controllable
ICT&IED	Without	With

Many aspects for network configuration have been shown in Table 5, from which we know if much more information is available then network configuration could be changed with many new feature, such as with generator, mesh operation, bi-direction load flow, optional islanding operation, controllable storage and with ICT&IED.

Table 6 Simulation Mode

Aspects	PDN	ADS
Modelling mode	Serial	parallel
Distribution Function	determines	Probabilistic
Simulation Function	Step	Ladder
Analysis method	Sensitivity	Risk based
Simulation time	Segment	Window

Many aspects for simulation mode have been shown in

Table 6, from which we know if much more information is available during the ADS planning and operation, then simulation mode could be with many new functions, such as parallel modelling mode, probabilistic distribution function, ladder simulation function, risk based Analysis method and window simulation time.

Table 7 Management Mode

Aspects	PDN	ADS
Organization structure	Vertical	Horizontal
Decision base	Fixed value	Calculation value
Border of control	Static	Dynamic
Fault treatment	After event	Before event
Load Curve	unchanged t	Changeable
Technical Standard	Uniform	Diversity

From Table 7, we know if much more information is available, then it is possible to cope with ADS planning and operation with horizontal organization structure and so on.

Table 8 Control and Protection Mode

Aspects	PDN	ADS
Protect Signal	absolute	relative
Control signal	centralized	distributed
Information based	accuracy	fuzzy
Fault control	passive	active
Feedback mode	reactive	proactive

From Table 8, we know if much more information is available, then it is possible to cope with ADS planning and operation with the relative protection signal and so on.

4. A SIMPLIFIED ADS PLANNING INFORMATION MODEL

The simplified module of ADS planning

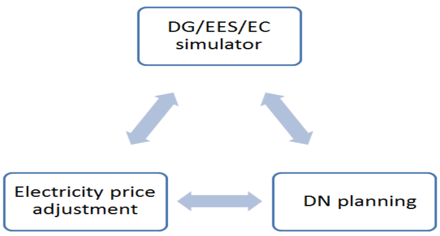

Figure 1 Architecture of ADS planning module

As shown in Figure 1, three main modules of ADS planning are pricing policy adjustment， Distribution Network(DN) planning, and dynamic load simulator which consists of Generations (DG, RES), Electricity Energy storage (EES), interactive Load and Electricity Customers (EC). Information was exchanged between the various modules: firstly, a preliminary proposal was given by DN planning module based on the initial load distribution and electricity price, secondly, electricity price was adjusted by the price policy module based on the load distribution and the DN planning, thirdly, load distribution was changed by dynamic load simulator based on the price and the DN planning. The whole procedure is doing so constantly back and forth until outputs of the three modules were no longer change.

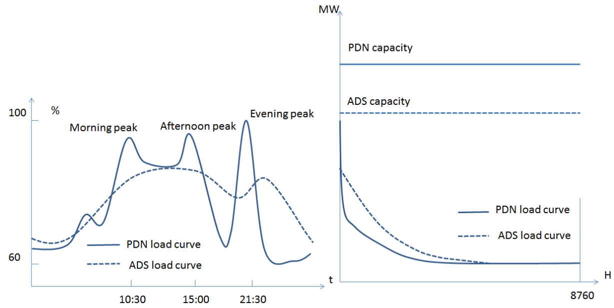

Figure2 Load Curves under PDN and ADS Planning

For the sack of system security for ADS, the traditional power load is suggested to be divided into three parts: the basic protection load, two-way interactive load, unidirectional load. Figure 2(left) shows that the three peaks of the PDN daily load curve could be significantly shifted into the daily load curve of ADS which is relatively smooth and flat under the combined action of DG, RES, EES and interactive load.

Figure 2(right) shows, the annual load duration curve of ADS is significantly reduced because of the combined action of DG, RES, EES and interactive load, peak load, and at same time, PDN and ADS's load duration curves almost are overlapping because of the basic protection load and unidirectional load are not changed.

Because the growth rate of the maximum load of the power system is often much larger than the speed of growth in electricity demand, the PDN was configured by the maximum load, which leads to equipment utilization rate getting lower and lower and leads to the increasingly high cost of system operation either. The effectiveness of the ADS is to reduce the peak load and to get a smooth load curve, as shown in Figure 2.

Therefore, the ADS planning would be realized when appropriate price policy makes a balance between various stakeholders. Take full advantage of the characteristics of the dynamic load what ADS can achieve, a great reduction in transmission investment would be brought, which is much lower than the peak growth rate by passive load and equipment utilization is much higher than by PDN, thereby reducing the costs of system operation. All sides, such as Electricity customers, DG, RES, EES and power companies, can share the benefit from the peak reduction.

Object classification and basic attributes

Most of the equipment parameters needed in the traditional distribution system planning were provided by many kind of information system in China and world else. But those information systems could not provide the information for ADS planning, such as electricity price sensitivity of customers, typical information for power consumption curve, operating characteristics ADS objects and so on.

Simplified device objects' properties of ADS planning are shown in Table 9, in which electricity customers, EVs, energy storage station, EV charging stations, EV charging pile, DG, RES are new type objects with respect to the PDN planning. These new objects can be called ADS object.

Table 9 Objects used in ADS Planning

Object	Members
electricity customer	access node, capacity, type, price sensitivity curve, typical power consumption curve，resource
electric vehicle(EV)	battery capacity, charging curve, discharging curve, current electricity, typically parked characteristics
energy storage station	access node, capacity, type, charging curve, discharging curve, current electricity
EV charging station	access node, capacity, operating characteristics
EV charging pile	access node, capacity
DG	access node, capacity, type, price sensitivity curve, operating characteristics
RES	access node, capacity, type, price sensitivity curve, operating characteristics

Due to the existence of a complex interaction of electricity customers with the power company, electricity customers can no longer be reduced to a simple load in ADS planning like the way in PDN planning where electricity customers are simplified to load.

Functions and scale of the information system

Due to the two-way smart meters and the new clearing and settlement system of ADS, the detailed analysis and simulation of users' behavior will be a core function in ADS planning.
In addition, through the open ADS planning platform, power users can actively participate in the planning. According to dynamic price list given by the power companies, users could make self-planning its electricity, use the formation of the contract, and thus benefiting. Dynamic price list is the power companies to measure their own investment and benefits given to each user, the price of electricity traded in a particular period.

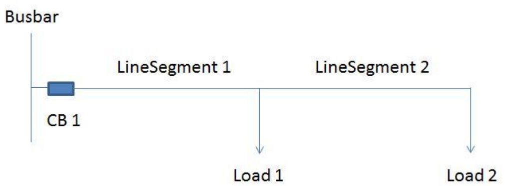

Figure 3 A sample of feeder

To explain the ADS information, a feeder shown in Figure 3 is used, which consists of two sections of lines and two power customer, in current DMS, power flow of LineSegment1 can be known form measurements on CB1, power flow of LineSegment2 is unknown. Inquiring Load2's monthly electricity consumption from MBMS, assuming a load curve and power factor, pseudo-measurements of LineSegment2's end side can be constituted, which is used to estimate the power flow on LineSegment2. Nevertheless constructed pseudo-measurements, its accuracy is very poor. Because smart meters is not to be installed for electricity customers in the PDN, the actual electricity customer load curve will not be given.
In ADS, the smart meter can record per minute or even a short time, changes in user load, each power user can be treated as a PQ node, and each piece feeder accurate power flow can be calculated. This can provide a basis for more detailed planning assessment.
The scale of information system for ADS planning is much larger than that for PDN planning, which means the needs to consider more than 4 million electricity customers in some Chinese major cities. It means that the ADS planning system is at least to be able to calculate the network more than 4 million node. A solution for large-scale computing of ADS planning would be provided by Cloud computing technology in the near future.

5. CONCLUSION

The information about the uncertainty of load for each node is unnecessary because of the larger reserve margin, and it does not have any economic value for PDN to measure the status of load and devices during operation with full measurement, full tele-signal and full remote control. However, it is important for ADS to keep the information for each node when the original passive electricity load has been upgraded to dynamic load with many new sources such as DG, RES, ESS and so on. Therefore, the development of information systems for ADS should closely track the development of a variety of new type electricity customers, make full use of smart meters to collect, aggregate and mining information, then a win-win situation not only in economic field but also in security field between power enterprises and various stakeholders can be built based these information systems.

References:

[1]H. Lee Willis, "Distribution system planning reference book", Marcel Dekker, Inc., New York, U.S.A., 2004
[2] Study Committee C6 Distribution Systems and Disperse generation [On-line]. Available: http://www.cigre-c6.org/
[3]C. D'Adamo, P. C. Taylor, S. Jupe, B. Buchholz, F. Pilo, C. Abbey and J. Marti: "Active distribution networks: General features, present status of implementation and operational practices", ELECTRA, 246, pp. 22-29, October 2009.