

Part A

At present, related research has given a comprehensive evaluation system of power grid investment decision indicators, which can be divided into input indicators and output indicators from the perspective of investment-benefit mechanism. The input indicators include various investment measures, external environmental factors and load factors. While the output indicators can be divided into economic benefits, power supply quality and operation efficiency. Specific indicators can be selected in combination with actual investment needs. Some common distribution network evaluation indexes (but not completely included) are given below:

Target layer	Criterion layer	Single indicator level
Input index	1. Grid structure	Line connection rate
		Reactive power compensation ratio
		Average number of segments
		Average power supply radius
	2. Equipment level	Average cross-sectional area of line
		Average distribution capacity
		Cable rate
		Insulation rate of overhead lines
		Automation rate
		Proportion of transformers over 30 years
		Proportion of lines over 30 years
	3. Natural factor	Average annual sunshine hours
		Annual average wind power density
		Duration of bad weather
	4. Load factor	Annual maximum load
		Annual maximum load utilization hours
	5. Energy factor	Proportion of new PV installed capacity
		Proportion of new PW installed capacity
		Quantity of electric vehicles
Output index	6. Power supply quality	Power supply reliability
		Average outage frequency of system
		Voltage qualification rate
		Average outage duration of users
		System load loss
	7. Operation level	Line overload ratio
		Average line load rate
		Overload rate of distribution transformer
		Electricity loss rate
		Average load rate of distribution transformer
	8. Active ability	Consumption rate of clean energy

Part B

Part of the data used in the CASE STUDY is shown as follows:

Grid number				Sample1	Sample2	Sample3	Sample4	Sample5	Sample6	Sample7	Sample8	Se
1	Input	Grid structure	Line connection rate	0.1483	0.155084725	0.155705064	0.168200395	0.187774716	0.195778614	0.197956651	0.200084685	0.2
			Reactive power compensation ratio	0.5876	0.631883673	0.646991437	0.700338822	0.717337955	0.743749034	0.793309765	0.848048139	0.5
		Equipment level	Cable rate	0.09035	0.09390979	0.095111835	0.108389448	0.122653499	0.129301318	0.135275039	0.161788947	0.1
			Insulation rate of overhead lines	0.4626	0.479547982	0.512113649	0.549311723	0.583818486	0.588011364	0.633502062	0.68959579	0.1
			Automation rate	0.3178	0.343899325	0.367542404	0.372136684	0.407861805	0.44273399	0.445113685	0.453682123	0.5
			Proportion of transformers over 30 years	0.44699	0.434586028	0.424427579	0.37996879	0.341021989	0.310798915	0.275562088	0.26522851	0.2
			Proportion of lines over 30 years	0.4622	0.437645625	0.419100392	0.378866754	0.348510055	0.311655117	0.285631915	0.264495153	0.2
		Natural factor	Average annual sunshine hours	0.44093	0.457444833	0.488509495	0.5	0.462727273	0.479679917	0.449242046	0.420082153	0.4
		Load factor	Annual maximum load utilization hours	0.42477	0.416120138	0.403939167	0.428322404	0.436538406	0.41391778	0.409439942	0.424626442	0.4
		Energy factor	Proportion of new PV installed capacity	0.01992	0.06	0.06564	0.08195154	0.089900839	0.091204402	0.101373692	0.106746498	0.1
			Proportion of new PW installed capacity	0.10376	0.103986385	0.105810874	0.112303814	0.113079731	0.119422476	0.12440565	0.129698545	0.1
	Output	Power supply quality	Power supply reliability	0.52172509	0.580587798	0.640250018	0.734374505	0.772449729	0.819846534	0.846729165	0.875035631	0.5
			Average outage frequency of system	0.005389967	0.004556923	0.004086719	0.002859463	0.002161471	0.001738709	0.001314166	0.00092529	0.0
			Voltage qualification rate	0.470076703	0.511205415	0.539013432	0.61152095	0.660759288	0.714126093	0.754825295	0.791099691	0.0
			System load loss	4142.515931	4117.282556	4087.125256	4036.087651	3989.256065	3995.566875	3958.516676	3910.971191	38
		Operation level	Line overload ratio	0.294828418	0.241118851	0.222651695	0.197143267	0.177777866	0.157367648	0.144917945	0.141023091	0.1
			Average line load rate	0.417770733	0.424867206	0.429908605	0.446006415	0.457139452	0.468059799	0.48082146	0.4941799	0.1
			Overload rate of distribution transformer	0.055129271	0.07228767	0.05032147	0.058912932	0.047204117	0.067395935	0.067973086	0.046698593	0.0
			Electricity loss rate	0.13606392	0.136270204	0.129584805	0.113910561	0.106062735	0.094948262	0.093955082	0.0885038	0.0
			Average load rate of distribution transformer	0.465607487	0.470899354	0.473185566	0.481360911	0.484065074	0.487599515	0.489513078	0.492257196	0.4
		Active ability	Consumption rate of clean energy	0.723286924	0.737923715	0.752660446	0.774399487	0.782495674	0.789863511	0.804034437	0.817432042	0.0
2	Input	Grid structure	Line connection rate	0.2845	0.290403375	0.303544128	0.335719805	0.34478424	0.368531255	0.372492966	0.375286663	0.4
			Reactive power compensation ratio	0.4198	0.451590309	0.477577279	0.520081656	0.529112165	0.573172778	0.592660653	0.605214283	0.0
		Equipment level	Cable rate	0.273	0.286689	0.318798168	0.327542346	0.37194773	0.395699249	0.439226167	0.482584064	0.4
			Insulation rate of overhead lines	0.5173	0.519322173	0.546421348	0.588297093	0.620920841	0.634411757	0.680781489	0.699348257	0.1
			Automation rate	0.2497	0.2569413	0.262690362	0.283639918	0.309628425	0.339584976	0.349602732	0.383645298	0.1
			Proportion of transformers over 30 years	0.39622	0.37541845	0.351438597	0.314361825	0.296443201	0.276618562	0.249613674	0.227834881	0.2
			Proportion of lines over 30 years	0.46173	0.460396113	0.432670036	0.394787371	0.354343598	0.342689631	0.312761403	0.295559526	0.2
		Natural factor	Average annual sunshine hours	0.45853	0.486458645	0.495347572	0.484720115	0.5	0.5	0.5	0.5	0.5
		Load factor	Annual maximum load utilization hours	0.44736	0.447892571	0.457767536	0.468819352	0.484513638	0.487536081	0.490647025	0.504642147	0.5
		Energy factor	Proportion of new PV installed capacity	0.01707	0.06	0.0757	0.089982067	0.119466191	0.119784767	0.130964679	0.172305862	0.2
			Proportion of new PW installed capacity	0.12484	0.15068188	0.172869787	0.208437745	0.209584153	0.261508627	0.295570126	0.352171805	0.1
	Output	Power supply quality	Power supply reliability	0.773276506	0.80024086	0.833056562	0.87256288	0.89105061	0.913725164	0.935154784	0.934923173	0.5
			Average outage frequency of system	0.003800915	0.003423723	0.002723498	0.001973696	0.001487482	0.001140477	0.000878612	0.000707743	0.0
			Voltage qualification rate	0.565631137	0.604658381	0.673921922	0.736730703	0.811139234	0.850993665	0.904857001	0.936879718	0.5
			System load loss	4058.513067	4042.712868	4022.825393	3991.814138	3923.906981	3915.194346	3886.098059	3875.635694	38
		Operation level	Line overload ratio	0.259766336	0.249142722	0.212404264	0.186402255	0.177521753	0.151621146	0.124833619	0.14145125	0.1
			Average line load rate	0.440270117	0.449094904	0.465621932	0.47976041	0.498507955	0.511056209	0.524711408	0.533742573	0.5
			Overload rate of distribution transformer	0.058540649	0.072335492	0.054699344	0.073023122	0.068612375	0.067699421	0.074948659	0.064455253	0.0
			Electricity loss rate	0.114728047	0.109341689	0.101560503	0.092506424	0.095962387	0.086870072	0.08647796	0.077740398	0.0
			Average load rate of distribution transformer	0.466000961	0.468925536	0.473993997	0.479130006	0.483559079	0.486650048	0.489279443	0.490491613	0.4
		Active ability	Consumption rate of clean energy	0.727283251	0.727513684	0.75060499	0.768334467	0.785388297	0.797075654	0.808105304	0.811943561	0.0

3	Input	Grid structure	Line connection rate	0.1565	0.16152365	0.166934692	0.169739195	0.170927369	0.187814994	0.196153979	0.202273983	0.2	
			Reactive power compensation ratio	0.2066	0.23185685	0.258462424	0.266183988	0.27729717	0.301387362	0.316079995	0.337612945	0.3	
		Equipment level	Cable rate	0.29335	0.318708478	0.331421405	0.354584079	0.390357672	0.430304274	0.439388475	0.463017811	0.4	
			Insulation rate of overhead lines	0.3933	0.4070655	0.437188347	0.445932114	0.498552103	0.558565313	0.566524869	0.60101207	0.6	
		Automation rate	0.2938	0.34116056	0.355966928	0.391777201	0.392168978	0.447386371	0.482103553	0.551815727	0.5		
		Proportion of transformers over 30 years	0.31369	0.310329036	0.290290647	0.274614952	0.259197284	0.256086916	0.233148845	0.210167031	0.2		
	Output	Power supply quality	Proportion of lines over 30 years	0.3293	0.302571817	0.285930367	0.283976509	0.27574119	0.229968153	0.201452102	0.185705263	0.1	
			Natural factor	Average annual sunshine hours	0.53642	0.518879066	0.518308299	0.535775289	0.561867545	0.565126377	0.529184339	0.49	0.2
		Load factor	Annual maximum load utilization hours	0.53296	0.534990324	0.543448266	0.564590991	0.58655627	0.60331502	0.622017786	0.624180038	0.6	
		Energy factor	Proportion of new PV installed capacity	0.01491	0.06	0.06428	0.083349733	0.103298103	0.107016835	0.110370029	0.138477596	0.1	
			Proportion of new PW installed capacity	0.11959	0.1339408	0.140347635	0.158522654	0.162062993	0.180754258	0.209012174	0.21301824	0.2	
		Power supply reliability	0.753967415	0.772088098	0.805626603	0.819715507	0.85022119	0.884388045	0.892808436	0.903513534	0.9		
4	Input	Grid structure	Average outage frequency of system	0.004202464	0.00366864	0.003146224	0.00273789	0.002260391	0.001634721	0.001387887	0.001120807	0.0	
			Voltage qualification rate	0.568292684	0.629028959	0.665971222	0.707076047	0.766578412	0.841687977	0.861446482	0.894747344	0.9	
		Operation level	System load loss	4027.756014	4007.048246	3948.202518	3966.000165	3911.467485	3922.504023	3876.558395	3878.152692	38	
			Line overload ratio	0.299346227	0.300828575	0.24422901	0.26685449	0.244867641	0.215970561	0.245034478	0.235645323	0.2	
		Average line load rate	0.453695677	0.464177276	0.472718085	0.482021481	0.496878328	0.51195395	0.517936794	0.525310101	0.2		
		Overload rate of distribution transformer	0.07038675	0.064814162	0.061328772	0.050957431	0.060095288	0.073286121	0.060587259	0.052632707	0.0		
	Output	Power supply quality	Electricity loss rate	0.132755318	0.133597607	0.126588787	0.122450544	0.110039605	0.106420906	0.101836089	0.100729344	0.0	
			Average load rate of distribution transformer	0.47810612	0.479735891	0.482144845	0.484168318	0.486397626	0.489743315	0.491355634	0.491834313	0.0	
		Active ability	Consumption rate of clean energy	0.684318288	0.692542946	0.712540906	0.723368688	0.739993738	0.762809679	0.772320067	0.785843297	0.7	
			Line connection rate	0.37045	0.392121325	0.434813534	0.435030941	0.466461927	0.505819652	0.563862457	0.606011175	0.6	
		Reactive power compensation ratio	0.3419	0.360576288	0.402718641	0.447823129	0.479450637	0.529073778	0.534033845	0.575955502	0.6		
		Equipment level	Cable rate	0.38315	0.416265107	0.445998329	0.487348746	0.545969838	0.603140679	0.658715785	0.659468603	0.6	
5	Input	Grid structure	Insulation rate of overhead lines	0.4237	0.471525138	0.47635827	0.487016786	0.520620945	0.533246003	0.579905028	0.608827791	0.6	
			Automation rate	0.3841	0.410282817	0.456986677	0.529266737	0.608480325	0.614159475	0.618049151	0.643492175	0.6	
		Operation level	Proportion of transformers over 30 years	0.3226	0.285931133	0.260435607	0.22410484	0.196913453	0.194320759	0.171002268	0.156923081	0.1	
			Proportion of lines over 30 years	0.33475	0.311987	0.287236031	0.283597708	0.278351151	0.27208825	0.257123396	0.221126121	0.1	
		Natural factor	Average annual sunshine hours	0.6487	0.64837565	0.637353264	0.631362143	0.654154317	0.67430227	0.7	0.63217	0.6	
		Load factor	Annual maximum load utilization hours	0.55064	0.560306791	0.583652907	0.584398686	0.592093269	0.600941774	0.627650297	0.651535878	0.6	
	Output	Power supply quality	Energy factor	Proportion of new PV installed capacity	0.09753	0.10429208	0.111592526	0.12033394	0.130802993	0.136296719	0.139817717	0.145340517	0.2
			Proportion of new PW installed capacity	0.11629	0.125383878	0.132330145	0.132488941	0.145207879	0.156766427	0.182288001	0.199605361	0.2	
		Active ability	Power supply reliability	0.707399184	0.771071164	0.820200974	0.857614899	0.893222127	0.91659843	0.947363225	0.9497236	0.9	
			Average outage frequency of system	0.002010513	0.001491979	0.00105494	0.000779937	0.000524677	0.000416856	0.000275289	2.07E-04	1.6	
		Voltage qualification rate	0.207289548	0.339312549	0.497090987	0.61235103	0.740896877	0.828457449	0.88820403	0.910473177	0.9		
		System load loss	3988.966598	3940.839893	3938.660748	3905.543359	3888.056508	3881.796461	3838.395841	3838.887104	38		
6	Input	Grid structure	Line overload ratio	0.223170443	0.185191347	0.163172411	0.134661728	0.14162059	0.128359384	0.086329064	0.096430523	0.6	
			Average line load rate	0.491878891	0.507864204	0.522052952	0.532764505	0.541475681	0.54681157	0.548651666	0.549728108	0.6	
		Operation level	Overload rate of distribution transformer	0.063423549	0.072666235	0.053180454	0.062632098	0.068415441	0.064498337	0.047658684	0.048998313	0.6	
			Electricity loss rate	0.103925794	0.095958324	0.085921623	0.085403418	0.074497176	0.077607995	0.071420816	0.069848181	0.6	
		Average load rate of distribution transformer	0.485843986	0.489113051	0.491913432	0.494153129	0.495742964	0.496807319	0.498303462	0.498811328	0.6		
		Active ability	Consumption rate of clean energy	0.756342642	0.775857492	0.791667806	0.800188022	0.816418178	0.825786747	0.83762691	0.841451596	0.6	
	Output	Power supply quality	Line connection rate	0.41493	0.443053033	0.461759717	0.501471053	0.533119448	0.555036581	0.610786922	0.635421994	0.6	
			Reactive power compensation ratio	0.4066	0.451500257	0.464464765	0.488616932	0.491339227	0.555985431	0.610472003	0.692188041	0.2	
		Equipment level	Cable rate	0.3521	0.3814249	0.392540711	0.42635529	0.429522501	0.441917293	0.468179806	0.520816593	0.2	
			Insulation rate of overhead lines	0.3933	0.4070655	0.437188347	0.445932114	0.498552103	0.558565313	0.566524869	0.60101207	0.6	
		Automation rate	0.2938	0.34116056	0.355966928	0.391777201	0.392168978	0.447386371	0.482103553	0.551815727	0.5		
		Proportion of transformers over 30 years	0.31369	0.310329036	0.290290647	0.274614952	0.259197284	0.256086916	0.233148845	0.210167031	0.2		