2017年 2 月 13 日
第二回 TWG（インテリムワークショップ）

THE PROJECT FOR MASTER PLAN STUDY ON NATIONAL POWER DEVELOPMENT IN THE FEDERAL REPUBLIC OF NIGERIA

TECHNICAL WORKING GROUP (TWG)

WORKSHOP

13th February 2017

JICA Study team

CONTENTS

1. OUTLINE OF THE STUDY

Item	Description
Objectives	Formulation of National Power System Development for 25 years Technical Transfer to the counterparts of Nigeria
Target Facility	Electric Power generation facilities and power system facilities of not less than 66/33kV substation facilities and transmission system owned by TCN
Implementation Agency	Federal Ministry of Power, Works and Housing
Scope of Work	Formulation of National Power System Development including power demand forecast, power generation development, power system development and investment plan

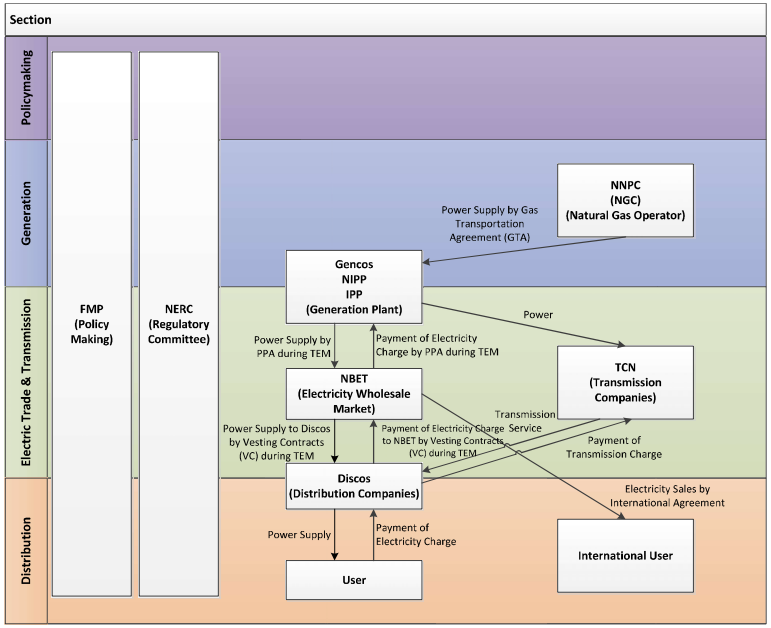
2. CONTENTS OF THE STUDY-1

Contents	Outline
1. Review of the Power Sector	■ Review of organizational and legal framework, legislation, power tariff and other policy related to the Power Sector ■ Review and analysis of the current power supply situation ■ Review of the existing power supply facilities
2. Primary Energy Analysis	■ Review of energy policy, energy supply and demand, and organizational structure ■ Review of primary energy as a domestic production ■ Outlook of the primary energy supply and demand
3. Power Demand Forecast	■ Review of method for power demand forecast ■ Formulation of power demand forecast ■ Power demand forecasting up to 2040
4. Study of optimization of power development plan	■ Data collection of the existing power plants ■ Data collection and analysis of planned new / expansion plan for power plants ■ Study of optimization of power development plan
5. Formulation of Power System Development Plan	■ Data collection of the existing power system ■ Data collection and analysis of planned new / expansion plan for transmission and substation facilities ■ Coordination with "Development of Power System Master Plan" ■ Study of power system development plan

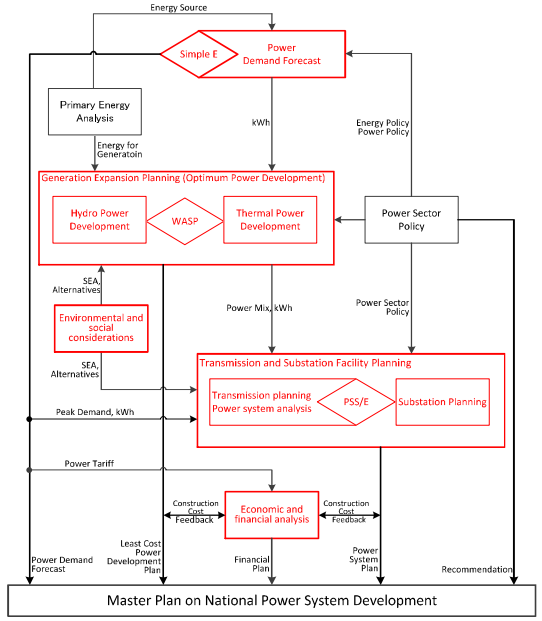
2. Contents of the Study-2

Contents	Outline
6. Environmental social considerations	■ Data collection of organizational structure and regulation framework for environmental social considerations ■ Data collection and analysis of prioritized projects ■ Implementation of SEA
7. Formulation of Master Plan on National Power System Development	■ Formulation of optimization of power development plan ■ Formulation of Power System Development Plan ■ Long-term investment plan and economic evaluation ■ Marshaling of the formulation of Master Plan on National Power System Development
8. Policy Recommendation	■ Recommendation of organizational and legal framework, legislation, power tariff and other policy related to the Power Sector shall be made in order to realize the master plan.
9. Technical Transfer	■ The master plan shall be formulated in collaboration work between the study team and the Nigerian counterparts. ■ Classroom training, actual data and software to formulate the master plan shall be utilized in the workshop. ■ How to Update Master Plan
10. Counterpart program in Japan	■ In order to make the master plan public widely and exchange information and opinions, seminar shall be hold in Japan. ■ Introduction of Power sector policy or institutional framework in Japan and facility tour

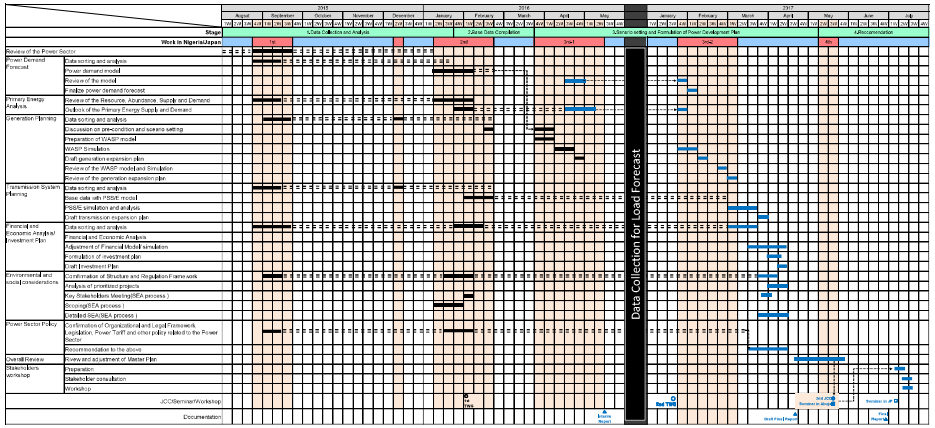
3. Power Supply flow



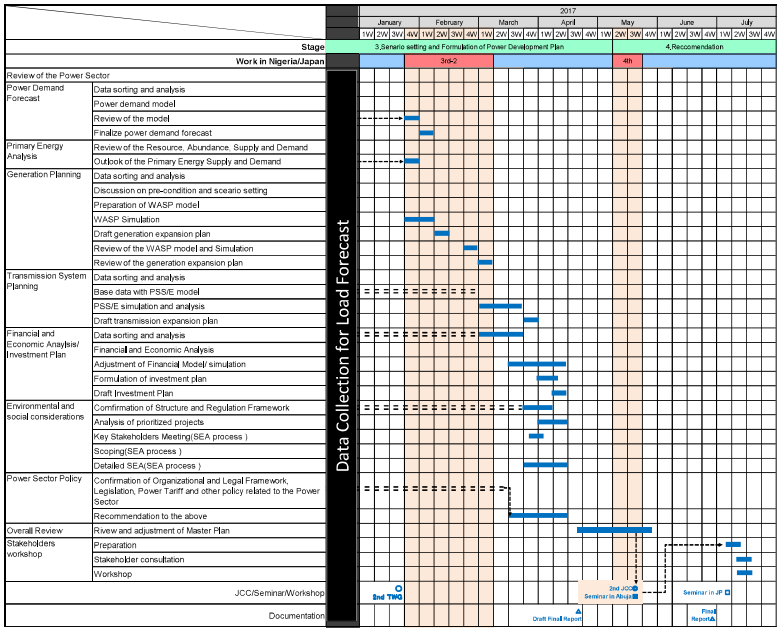
4. Master Plan Formulation



5. Schedule of the Study-1



5. SCHEDULE OF THE STUDY-2



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Thank you for your attention

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MASTER PLAN STUDY ON NATIONAL POWER SYSTEM DEVELOPMENT IN THE FEDERAL REPUBLIC OF NIGERIA

1

TWG on Power Demand Forecasts

Feb 2017

Contents

1. Preconditions on Power demand forecasts

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1.1 Discussing Social Economic conditions

Nigerian C/P
FM of Power, Works & Housing
TCN & NCC

JICA
Study Team

	Ministry and Authority	Visited Date
TCN	Transmission Company of Nigeria	19th Jan 2016
REA	Rural Electrification Authority	19th Jan 2016
ECN	Energy Commission of Nigeria	20th Jan 2016
NBS	National Bureau of Statistics	20th Jan 2016
MBNP (NPC)	Ministry of Budget and National planning	21st Jan 2016
NNPC	Nigerian National Petroleum Corporation	21st Jan 2016
NERC	Nigerian Electricity Regulatory Commission	27th Jan 2016
NBET	Nigeria Bulk Electricity Trade	29th Jan 2016

1.2 Population & GDP Forecasts

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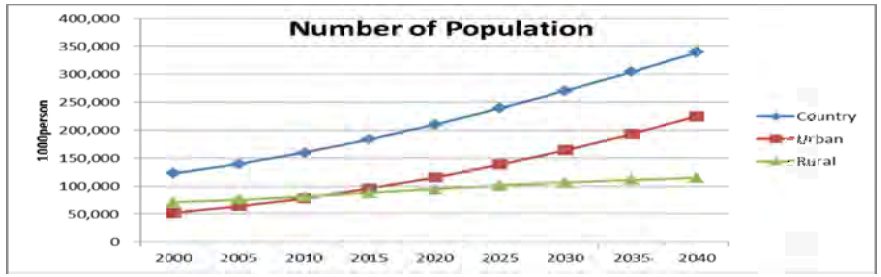

Source: United Nations : World Population Prospects 2012 Division

< GDP growth rate >

Scenario of GDP	2015-2020	2020-2025	2025-2030	2030-2035	2035-2040
Base GDP	4.3 %	6.5 %	6.5 %	6.5 %	6.5 %
High GDP	4.3 %	8.0 %	8.0 %	8.0 %	8.0 %
Low GDP	4.3 %	5.0 %	5.0 %	5.0 %	5.0 %

Reference FMBNP, Vision 20 2020 and IMF studies

1.3 Crude oil price outlook

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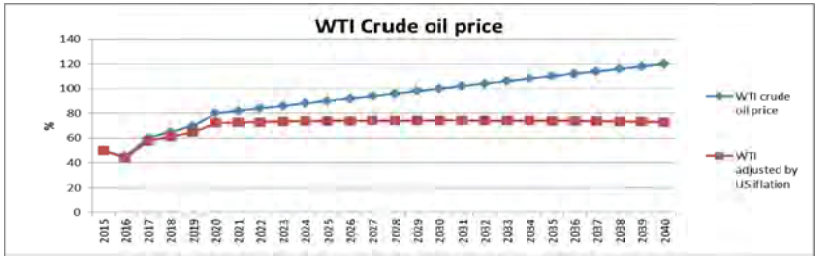
Organization	Publication	Latest version
International Energy Agency (IEA)	World Energy Outlook（WEO)	2016 version
Energy Information Agency (EIA, USA)	International Energy Outlook	2016 version
The Institute of Energy Economics, Japan(IEEJ)	Asia/ World Energy Outlook	2016 version



a. Source: Actual data from BP statistics.
b. Recent data from The Institute of Energy Economics, Japan
c. Brent oil price is nearly same to WTI price. (Brent = WTI + $2/bbl)

2. Country Wide Power Demand Forecasts

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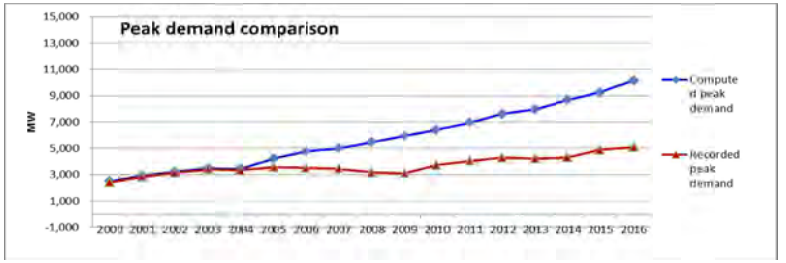
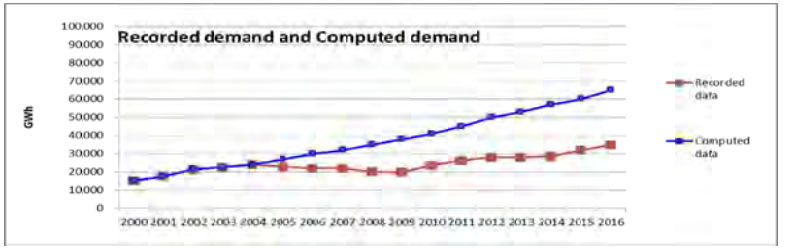
2.1 Recorded demand and Computed demand





Recorded demand means "With constrain demand" and computed demand is "Without constrain demand".

2.2 Computed and Recorded demand Forecasts

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MW

			2015	2020	2025	2030	2035	2040
Computed	On grid	Domestic peak demand	9,240	14,070	22,810	35,310	47,140	60,040
	Off grid power	Power demand (Off grid)	160	1,400	3,150	4,340	5,950	8,190
	On + Off grid	Peak demand	9,390	15,470	25,960	39,650	53,090	68,230
	Export	Export power demand	260	330	500	710	890	1,060
	Country power	Peak demand	9,660	15,800	26,460	40,360	53,990	69,290
Recorded	On grid	Domestic peak demand	4,880	9,140	21,670	35,310	47,140	60,040
	Off grid power	Power demand (Off grid)	160	1,400	3,150	4,340	5,950	8,190
	On + Off grid	Peak demand	5,040	10,540	24,820	39,650	53,090	68,230
	Export	Export power demand	260	330	500	710	890	1,060
	Country power	Peak demand	5,300	10,870	25,320	40,360	53,980	69,290

Note: Off grid demand connected to TCN is increased with real GDP growth rate.
Note: Export is estimated by Elasticity to TCN demand growth rate, the elasticity is 0.7

%

Computed demand	Unit	2015/10	2020/15	2025/20	2030/25	2035/30	2040/35	2040/15
Energy Demand	%	8.4	7.0	10.2	9.1	6.0	5.0	7.4
Peak demand	%	7.6	8.8	10.2	9.1	6.0	5.0	7.8
Recorded demand	**Unit**	**2015/10**	**2020/15**	**2025/20**	**2030/25**	**2035/30**	**2040/35**	**2040/15**
Energy Demand	%	5.3	12.8	18.8	10.3	6.0	5.0	10.4
Peak demand	%	5.6	13.4	18.8	10.3	6.0	5.0	10.6

2.3 Comparison Computed and Recorded demand

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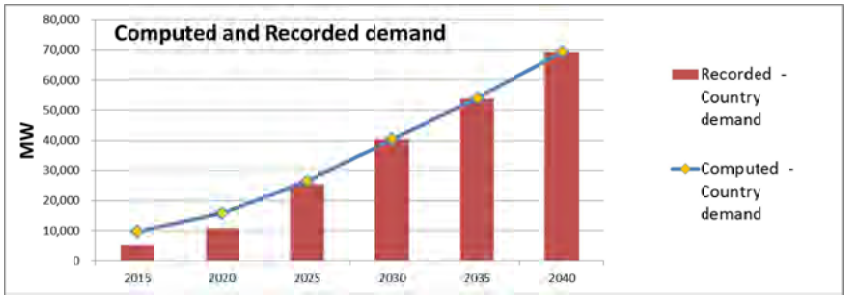
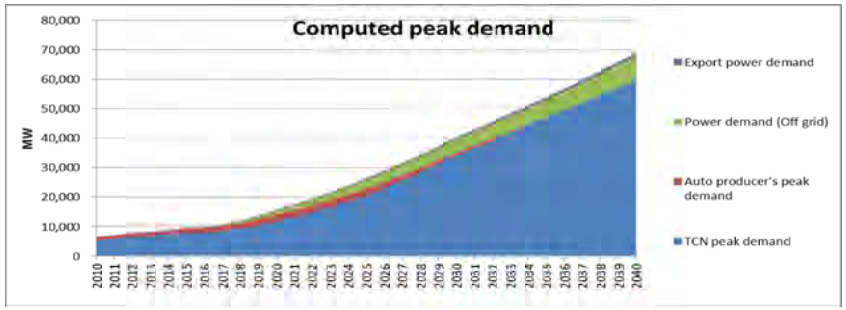
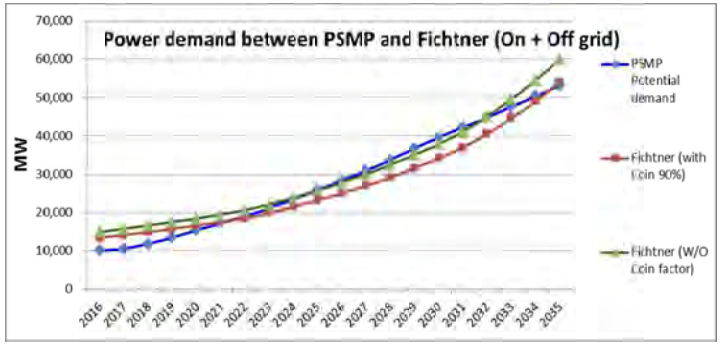




2.4 Load demand comparison of Fichtner study and PSMP

8



MW

	2016	2017	2018	2019	2020	2025	2030	2035
PSMP Potential demand	9,822	10,496	11,770	13,506	15,469	25,964	39,650	53,093
Fichtner (with Coin 90%)	13,442	14,171	14,938	15,748	16,601	23,185	34,128	54,000
Fichtner (W/O Coin factor)	14,936	15,745	16,598	17,498	18,445	25,761	37,920	60,000

Source: PSMP = Power Demand Forecasting Model by PSMP
Fichtner : Regional Survey implemented by TCN and Fichtner

3. Region wise power demand forecasts

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3.1 Regional survey results in 2016

		C	D	E	F	G	H
NAME OF DISCO	Unit	DISCO LOAD DEMAND FROM 2016 FIELD MEASURENT	HISTORIC 33kVPEAK LOAD COLLECTED IN 2016	DISCO ESTIMATE ON-GRID SUPPRESSED LOAD	DISCO ESTIMATED OFF GRID SUPPRESSED (POTENTIAL) LOAD	Potential demand On grid in 2016	Potential demand On + Off in Future
AEDC	MW	762	577	270	381	1,033	1,414
BEDC	MW	1,223	777	163	221	1,386	1,607
EEDC	MW	1,027	803	380	287	1,406	1,694
IBEDC	MW	1,286	1,119	184	280	1,470	1,749
IKEDC+EKEDC	MW	2,566	1,834	683	716	3,249	3,965
JEDC	MW	399	416	44	143	443	586
KAEDCO	MW	602	632	93	342	695	1,037
KEDCO	MW	708	514	187	224	895	1,119
PHEDC	MW	948	885	130	230	1,078	1,308
YOLA	MW	280	305	35	365	315	679
TOTAL	MW	9,801	7,861	2,169	3,188	11,969	15,157
Coincident rate 90%	MW	8,821	7,075	1,952	2,869	10,772	13,641

Source: The survey is conducted by TCN and Fichtner

3.2 DISCO wise electrification rate & electrified population

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			2014	2015	2020	2025	2030	2035	2040
Electrification rate	Abuja	%	**54**	57	76	**100**	100	100	100
	Benin	%	**80**	82	90	**100**	100	100	100
	Enugu	%	**71**	73	86	**100**	100	100	100
	Ibadan	%	**80**	81	90	**100**	100	100	100
	Ikeja+EKO	%	**99**	99	100	**100**	100	100	100
	Jos	%	**40**	42	56	75	**100**	100	100
	Kaduna	%	**41**	44	58	76	**100**	100	100
	Kano	%	**36**	38	49	62	79	**100**	100
	Port Harcour	%	**61**	64	80	**100**	100	100	100
	Yola	%	**30**	32	42	56	75	**100**	100
	Total	%	57	59	71	85	95	100	100
Electrified Population	Abuja	1000 persons	5,041	5,484	8,331	12,632	14,441	16,463	18,711
	Benin	1000 persons	13,632	14,337	18,387	23,473	27,000	30,966	35,332
	Enugu	1000 persons	14,207	14,978	19,530	25,378	28,127	31,069	34,240
	Ibadan	1000 persons	15,612	16,420	21,059	26,902	30,928	35,437	40,449
	Ikeja+EKO	1000 persons	11,549	11,895	13,765	15,861	18,234	20,841	23,704
	Jos	1000 persons	8,943	9,737	14,858	22,608	34,319	38,943	44,017
	Kaduna	1000 persons	8,532	9,257	13,869	20,715	30,866	34,856	39,222
	Kano	1000 persons	9,160	9,894	14,499	21,168	30,828	44,753	50,892
	Port Harcour	1000 persons	10,803	11,647	16,910	24,431	28,065	32,148	36,653
	Yola	1000 persons	4,497	4,885	7,361	11,072	16,582	24,793	27,750
	Total	1000 persons	101,977	108,533	148,568	204,242	259,390	310,270	350,969

- Current electrification rate is 57% and almost 100% in 2030
- Some DISCOs are 100% up to 2025, and some are 100% in 2030
- Kano and Yola are 100% in 2035

3.3 DISCO wise peak demand

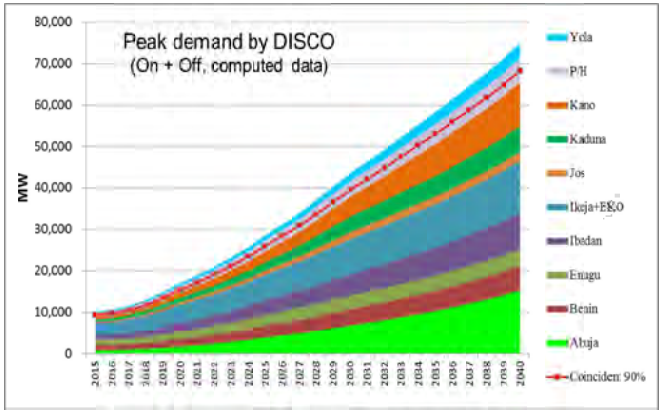
Unit: MW

		2015	2020	2025	2030	2035	2040	2040/15
Computed data	Abuja	885	1,779	3,987	6,806	10,327	15,308	12.1
On + Off	Benin	1,189	1,811	2,807	3,928	4,871	5,904	6.6
	Enugu	1,206	1,786	2,617	3,276	3,668	4,062	5.0
	Ibadan	1,260	2,106	3,470	5,144	6,754	8,676	8.0
	Ikeja+EKO	2,786	4,363	6,155	8,500	10,433	12,562	6.2
	Jos	380	618	1,045	1,703	1,926	2,149	7.2
	Kaduna	596	1,056	2,045	3,764	4,898	6,249	9.9
	Kano	767	1,412	2,614	4,792	7,813	10,620	11.1
	P/H	924	1,527	2,690	3,790	4,736	5,792	7.6
	Yola	270	574	1,107	1,870	2,906	3,582	10.9
DISCO total	Total	10,263	17,032	28,537	43,574	58,331	74,904	8.3
Concided rate 90%	Country	9,393	15,469	25,964	39,650	53,093	68,232	8.3

		2015	2020	2025	2030	2035	2040	2040/15
Recorded data	Abuja	468	1,215	3,807	6,806	10,327	15,308	15.0
	Benin	628	1,211	2,677	3,928	4,871	5,904	9.4
	Enugu	637	1,205	2,500	3,276	3,668	4,062	7.7
	Ibadan	666	1,412	3,310	5,144	6,754	8,676	10.8
	Ikeja+EKO	1,472	2,946	5,883	8,500	10,433	12,562	9.0
	Jos	201	424	1,000	1,703	1,926	2,149	10.0
	Kaduna	315	739	1,960	3,764	4,898	6,249	12.7
	Kano	405	952	2,495	4,792	7,813	10,620	14.0
	P/H	488	1,028	2,567	3,790	4,736	5,792	10.4
	Yola	143	429	1,070	1,870	2,906	3,582	13.8
DISCO total	Total	5,422	11,561	27,270	43,574	58,331	74,904	11.1
Concided rate 90%	Country	4,880	10,545	24,824	39,650	53,093	68,232	11.1

Source: Study team estimation

3.4 Peak demand shares by DISCO



Shares (%)

	2015	2040
Abuja	9%	20%
Benin	12%	8%
Enugu	12%	5%
Ibadan	12%	12%
Ikeja+EKO	26%	16%
Jos	4%	3%
Kaduna	6%	8%
Kano	8%	15%
P/H	9%	8%
Yola	3%	5%
Total	100%	100%
Peak MW	10,263	74,904
Coin 90%	9,393	68,232

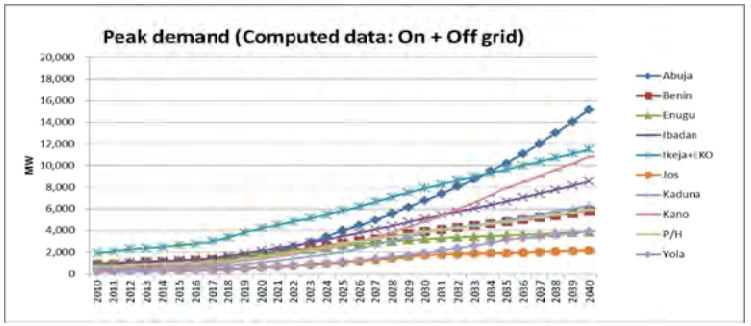
Note: Export is not included

Note: Coincident 90% (Country total) = DISCO total *0.9

3.5 Computed growth rate of On+Off grid

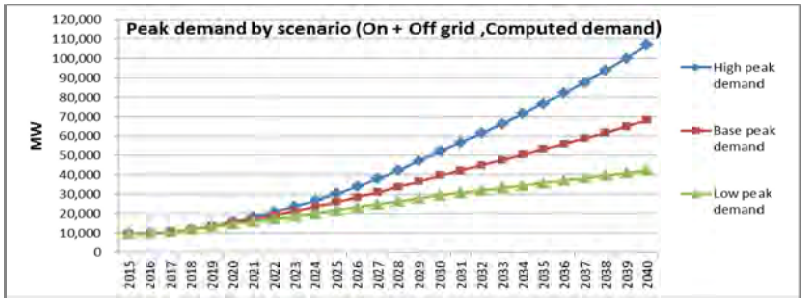
%

	2020/15	2025/20	2030/25	2035/30	2040/35	2040/15
Abuja	15.0	17.5	11.3	8.7	8.2	12.1
Benin	8.8	9.2	7.0	4.4	3.9	6.6
Enugu	8.2	7.9	4.6	2.3	2.1	5.0
Ibadan	10.8	10.5	8.2	5.6	5.1	8.0
Ikeja+EKO	9.4	7.1	6.7	4.2	3.8	6.2
Jos	10.2	11.1	10.3	2.5	2.2	7.2
Kaduna	12.1	14.1	13.0	5.4	5.0	9.9
Kano	13.0	13.1	12.9	10.3	6.3	11.1
P/H	10.6	12.0	7.1	4.6	4.1	7.6
Yola	16.3	14.0	11.1	9.2	4.3	10.9
Total	10.7	10.9	8.8	6.0	5.1	8.3
Coincident 90%	10.5	10.9	8.8	6.0	5.1	8.3



4. Peak demand by GDP Scenario

4.1 Peak demand (On + Off) by Scenario



Note: Export is not included

MW

	2015	2016	2017	2018	2019	2020	2025	2030	2035	2040	40/15
High peak	9,393	9,822	10,501	11,784	13,534	15,921	30,236	52,098	76,748	107,015	10.2
Base peak	9,393	9,822	10,496	11,770	13,506	15,469	25,964	39,650	53,093	68,232	8.3
Low peak	9,393	9,820	10,486	11,739	13,184	14,685	21,784	29,437	35,758	42,330	6.2

5. Update power demand forecasts

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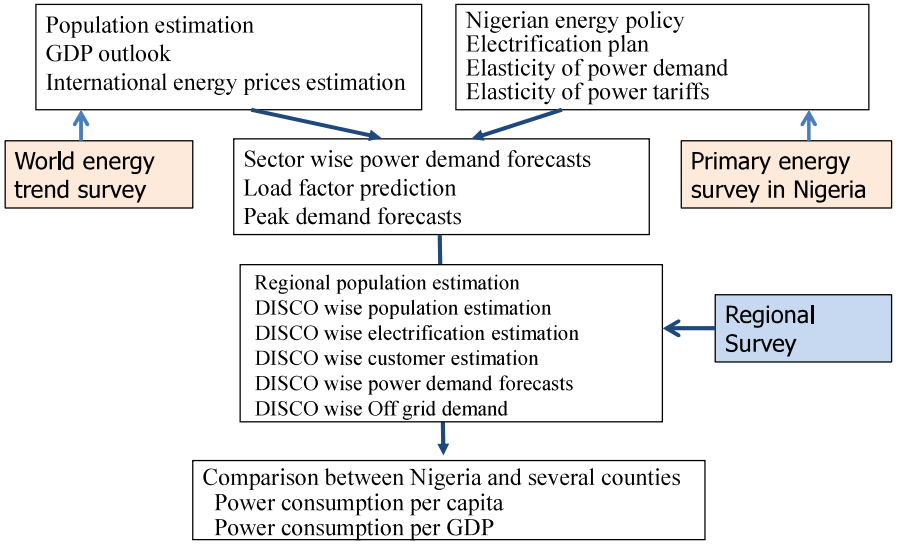
5.1 Procedures of Power demand forecasts



5.2 Social and economic forecasts

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Update items	Authorities
Population forecasts	NPopC, NBS
GDP outlook	NPC, NBS
Exchange rate	NPC, MOF, CBN
Inflation rate	NPC, MOF, CBN
Crude oil Price	MPR, NNPC
Power tariff	NERC

NPopC：National Population Committee

MPR: Ministry of Petroleum Resources

5.3 Power demand forecasts

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Update items	Authorities
Residential sector	TCN, NERC, ECN
Commercial sector	TCN, NERC, ECN
Public and Street sector	TCN, NERC, ECN
Transmission loss (T- loss)	TCN, NERC, ECN
Total power demands	TCN, NERC, ECN
Peak demand	TCN, ECN
Generation	TCN, ECN
Required capacity	TCN, ECN
Export	TCN, ECN
Off grid power demand	REA, TCN

5.4 DISCO wise power demand

Update items	Authorities
Regional Survey	TCN ,DISCOs
Sectoral customers	TCN ,DISCOs
Sectoral power demand	TCN ,DISCOs
On + Off grid power demand	TCN ,DISCOs

5.5 Task force image

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Task force	Authorities	Conductors
Social economic forecasts	NPC, MOF, NPopC, NBS, CBN	FMP
Energy supply conditions	ECN, MPR, NNPC	
Power demand forecasts	TCN, NERC	
DISCO power demand forecasts	TCN , DISCOs	
Off grid plans	REA , TCN	

Note: NPopC: National Population Commission
DISCOs: 11 DISCOs

THE PROJECT
FOR
MASTER PLAN STUDY ON NATIONAL POWER SYSTEM DEVELOPMENT
IN
THE FEDERAL REPUBLIC OF NIGERIA

Methodology and procedure of updating Generation Expansion Plan

February 2017

Technical Working Group

1. Introduction

- This manual covers the process and methodology of updating the generation expansion plan of National Power System Development (Master Plan).
- The least cost generation expansion plans will be formulated through simulation using WASP software. For details of WASP software, its manual can be referred and the description of how to use WASP is not included in this manual.
- Federal Ministry of Power, Works and Housing (FMPWH) is responsible for updating the generation expansion plan in cooperation with related agencies such as Nigerian Electricity Regulatory Commission (NERC), Transmission Company of Nigeria (TCN), Energy Commission of Nigeria (ECN), Nigeria Bulk Electricity Trading Plc (NBET), Gas Aggregation Company of Nigeria (GACN), Nigeria Gas Company (NGC), etc.

2. Flow of updating generation expansion plan

STEP-1: Data collection and update
(1) Power demand forecast
(2) Characteristics of existing power plants
(3) Ongoing and planned generation expansion (Fixed expansion)
(4) Variable expansion candidates (thermal and hydro)
(5) Fuel price, availability and reserve
(6) Power development policy

↓

STEP-2: WASP simulation using updated data and generation expansion scenarios, if any change is required

↓

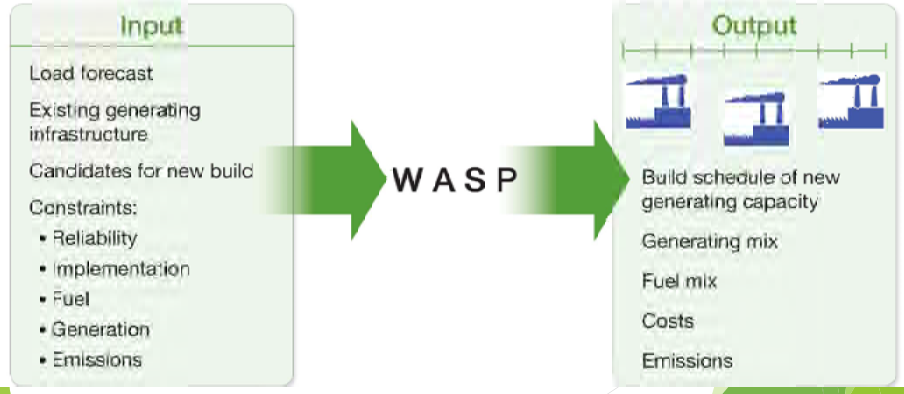
STEP-3: Evaluation of generation expansion scenarios from the aspects of (1) total generation cost, (2) energy balance/sustainability and (3) environment

↓

STEP-4: Formulation of revised generation expansion plan

[Reference] What is WASP?

WASP
Wien Automatic System Planning Package



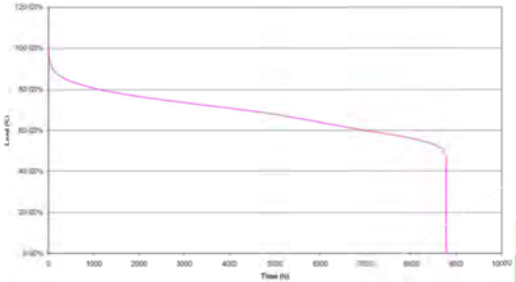
Source: IAEA (Aug.2009) "Tools and Methodologies for Energy System Planning and Nuclear Energy System Assessments"

2. Data collection and update

Type of data and information	Responsible organization						
	FMPWH	TCN	NERC	GENCOs	NBET	GACN	NGC
Power demand forecast		Update power demand forecast and load duration curve					
Characteristics of existing power plants				Update the characteristics of existing power plants			
Ongoing and planned generation expansion	Update the status of ongoing and planned generation expansion	Update the status of ongoing and planned generation expansion	Update the status of ongoing and planned generation expansion (IPP)		Update the status of ongoing and planned generation expansion (IPP)		
Variable expansion candidates	Update the variable expansion candidates						
Fuel price, availability and reserve						Update the fuel price, availability and reserve	Update the fuel price, availability and reserve
Power development policy	Update power development policy						

2.1 Power demand forecast

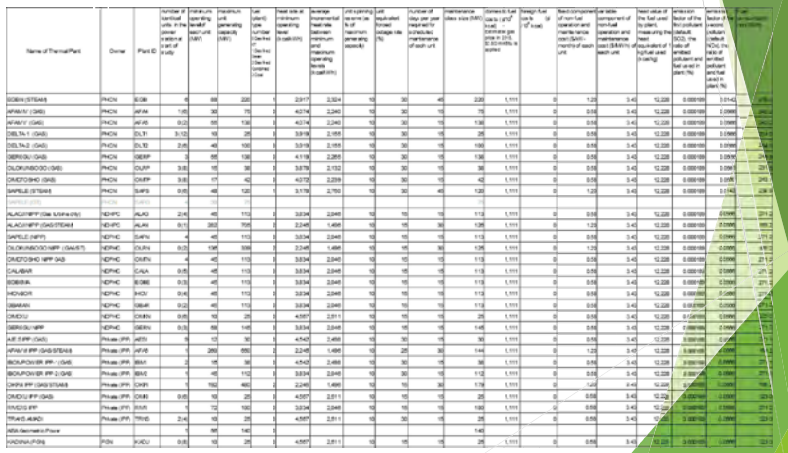
- Power demand forecast for nation-wide, grid connected customers shall be updated by TCN. Peak demand (MW) and energy demand (GWh) for each year of the planning period as well as monthly variation of the highest peak demand from January to December are necessary as the input data for WASP.
- Load duration curve which is represented the following figure is also an input of Loadsy (load system description) module of WASP and needs to be updated using the hourly load of the latest year.



Load duration curve

2.2 Characteristics of existing power plants

- Characteristics of existing thermal and hydro power plants, as shown in the following table needs to be updated. The information shall be collected by questionnaires to generation companies.



2.3 Ongoing and planned generation expansion

- Progress status of ongoing and planned generation projects need to be updated in order to evaluate how sure and when they will be online. Committed projects are treated as “fixed expansion” in WASP while projects in initial planning stages are deemed as “variable expansion” which commissioning year and required capacity are determined by WASP.

2.4 Variable expansion candidates
(1) Thermal power plants

- Variable expansion candidates for thermal power plants as shown in the following table will be updated if any other or different type of plants are applicable.

Plant type	Capacity	Efficiency	Cost	Plant life
Simple cycle gas turbine	100MW class	30.8%	$980/kW	30 years
	200MW class	34.7%	$680/kW	30 years
Combined cycle	300MW class	51.4%	$980/kW	30 years
	500MW class	54.0%	$941/kW	30 years
	1,000MW class	55.1%	$842/kW	30 years
Coal fired conventional	300MW class	40.7%	$2,500/kW	40 years
	700MW class	42.1%	$2,000/kW	40 years
	1,000MW class	43.0%	$2,000/kW	40 years

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2.4 Variable expansion candidates
(2) Hydro power plants

- Potential hydro sites which are identified through a study named "Screening for Hydropower Options with Associated Water Resources Development in the Niger Basin" assisted by the World Bank and conducted by Tractebel Engineering was used for the Project. Out of 64 sites identified by the WB study, 20 to 30 sites which have high ranking scores and large capacity were selected for hydro candidates for the Project.

Operation Records – Monthly output (MWh)

No.	Hydropower Station		Plant ID	Type	Installed Capacity (MW)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Output (MWh)
1	Prospecting sites(Large Scale)	NIG03	NIG3	R.Dam	190	65,793	39,530	22,839	17,543	38,672	74,962	96,750	96,750	93,629	96,750	93,629	96,750	833,600
2	Prospecting sites(Large Scale)	NIG02	NIG2	R.Dam	266	92,275	59,588	31,550	13,240	19,722	38,792	84,230	195,535	189,227	195,535	133,365	110,640	1,163,700
4	Prospecting sites(Large Scale)	BEN05-85	BEN5	Dam	239	36,322	16,173	12,335	22,506	62,456	129,354	135,563	138,867	134,387	138,867	134,387	86,586	1,047,800
3	Prospecting sites(Large Scale)	BEN06-85	BEN6	Dam	265	39,031	17,379	13,255	24,184	67,114	139,001	155,667	155,667	150,646	155,667	150,646	93,043	1,161,300
5	Prospecting sites(Large Scale)	BEN07	BEN7	RoR	196	34,113	16,605	12,068	18,771	50,277	100,298	111,305	111,305	107,714	111,305	107,714	75,227	856,700
6	Prospecting sites(Large Scale)	DON05	DON5	Dam	198	26,869	11,067	20,615	52,814	97,617	94,468	97,617	97,617	94,468	97,617	94,468	80,062	865,300
7	Prospecting sites(Large Scale)	BEN01-185	BEN1	Dam	203	28,449	13,270	6,159	5,458	21,445	56,600	140,525	140,525	135,992	140,525	135,992	63,458	888,400
8	Prospecting sites(Large Scale)	NIG01	NIG1	Dam	134	60,764	54,884	33,164	13,916	20,730	40,776	60,764	60,764	58,804	60,764	58,804	60,764	584,900
9	Prospecting sites(Large Scale)	BEN03	BEN3	Dam	101	20,387	9,179	548	6,370	20,800	52,102	57,937	57,937	56,068	57,937	56,068	45,667	441,000
1	Prospecting sites(Middle Scale)	BEN04-85	BEN4	RoR	88	17,754	7,994	4,235	5,547	18,113	4,550	61,516	61,516	59,532	61,516	42,060	39,769	384,188
2	Prospecting sites(Middle Scale)	KAT04	KAT4	RoR	36	4,590	1,761	2,630	6,664	16,753	18,221	18,829	18,829	18,221	18,829	18,221	13,552	157,100
3	Prospecting sites(Middle Scale)	KAT07	KAT7	Dam	52	6,648	2,550	3,810	9,653	24,268	26,695	27,585	27,585	26,695	27,585	26,695	19,631	229,400
4	Prospecting sites(Middle Scale)	BEN02	BEN2	RoR	35	15,524	8,705	4,043	3,498	13,764	15,023	15,524	15,524	15,023	15,524	15,023	15,524	152,700
5	Prospecting sites(Middle Scale)	KAT02	KAT2	Dam	67	8,357	3,206	4,790	12,135	30,506	34,611	35,765	35,765	34,611	35,765	34,611	24,677	294,800
6	Prospecting sites(Middle Scale)	TAR12	TR12	Dam	77	3,008	849	513	2,796	8,974	21,422	57,065	57,065	55,224	57,065	36,226	10,324	336,000
7	Prospecting sites(Middle Scale)	DON09	DON9	Dam	33	6,024	2,772	2,044	3,798	8,643	17,279	18,395	18,395	17,801	18,395	17,801	13,155	144,500
8	Prospecting sites(Middle Scale)	ANK13	AK13	RoR	20	5,084	3,239	2,063	12,208	2,576	3,081	8,387	11,425	11,057	11,425	11,057	7,899	89,500
9	Prospecting sites(Middle Scale)	TAR08	TAR8	Dam	38	9,538	4,388	3,235	6,013	13,683	17,894	18,490	18,490	17,894	18,490	17,894	18,490	164,500
10	Prospecting sites(Middle Scale)	TAR10	TR10	Dam	58	1,438	394	131	379	3,050	7,969	24,138	32,800	41,544	29,069	17,330	4,924	251,800
11	Prospecting sites(Middle Scale)	TAR06	TAR6	Dam	31	1,218	344	208	1,132	3,634	8,675	22,692	22,692	21,960	22,692	14,671	4,181	133,400
12	Prospecting sites(Middle Scale)	GON10-300	GN10	Dam	24	1,258	1,014	487	217	412	4,347	17,146	18,154	17,568	14,202	9,238	4,380	106,800
13	Prospecting sites(Middle Scale)	DON12	DN12	Dam	45	1,388	392	237	1,290	4,140	9,882	29,609	33,331	32,256	33,331	16,712	4,763	196,300
14	Prospecting sites(Middle Scale)	MAD05-360	MAD5	Dam	29	9,436	6,012	3,828	2,675	4,781	5,719	15,568	16,242	15,718	16,242	15,718	14,662	126,600
13	Prospecting sites(Middle Scale)	DON04	DON4	Dam	56	2,443	690	416	2,270	7,288	17,397	41,441	41,441	40,104	41,441	29,421	5,496	240,911
14	Prospecting sites(Middle Scale)	DON11	DN11	RoR	21	898	251	152	827	2,655	6,338	15,252	15,252	14,760	15,252	10,718	3,055	89,900

Operation Records – Monthly Availability (MW); O&M Cost; Construction Features as of 2016

No.	Plant ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	O&M Cost ($/kW.month) as of 2015	Project Cost (M USD)	Construction Period (Year)	COD	Plant Life (Year)
1	NIG3	129	86	45	36	76	152	190	190	190	190	190	190		231	5 (+5)	2026	50
2	NIG2	125	90	43	19	27	54	114	266	266	266	187	150		323	5 (+5)	2026	50
4	BEN5	63	31	21	40	108	230	234	239	239	239	239	149		458	5 (+5)	2026	50
3	BEN6	66	33	23	43	114	245	265	265	265	265	265	158		520	4 (+5)	2025	50
5	BEN7	60	32	21	34	88	182	196	196	196	196	196	132		396	5 (+5)	2026	50
6	DON5	54	25	42	110	198	198	198	198	198	198	198	162		414	4 (+5)	2025	50
7	BEN1	41	21	9	8	31	84	203	203	203	203	203	92		474	5 (+5)	2026	50
8	NIG1	134	134	73	32	46	93	134	134	134	134	134	134		448	4 (+5)	2025	50
9	BEN3	35	18	1	11	36	94	101	101	101	101	101	79		850	6 (+5)	2027	50
1	BEN4	25.31	12.62	6.04	8.17	25.82	6.70	87.70	87.70	87.70	87.70	61.96	56.70		146	3 (+3)	2022	50
2	KAT4	8.75	3.72	5.02	13.13	31.94	35.90	35.90	35.90	35.90	35.90	35.90	25.84		100	3 (+3)	2022	50
3	KAT7	12.63	5.36	7.24	18.95	46.10	52.40	52.40	52.40	52.40	52.40	52.40	37.29		147	3 (+3)	2022	50
4	BEN2	34.90	21.67	9.09	8.13	30.94	34.90	34.90	34.90	34.90	34.90	34.90	34.90		100	4 (+3)	2023	50
5	KAT2	15.73	6.68	9.01	23.60	57.40	67.30	67.30	67.30	67.30	67.30	67.30	46.44		347	3 (+3)	2022	50
6	TR12	3.63	1.14	0.62	3.49	10.84	26.74	76.70	76.70	76.70	76.70	45.23	12.47		444	3 (+3)	2022	50
7	DON9	10.81	5.50	3.67	7.04	15.51	32.03	33.00	33.00	33.00	33.00	33.00	23.60		308	3 (+3)	2022	50
8	AK13	9.08	6.40	3.68	20.40	4.60	5.68	14.98	20.40	20.40	20.40	20.40	14.10		255	3 (+3)	2022	50
9	TAR8	19.39	9.88	6.58	12.63	27.82	37.60	37.60	37.60	37.60	37.60	37.60	37.60		670	4 (+3)	2023	50
10	TR10	1.04	0.32	0.09	0.28	2.21	5.96	17.47	44.09	57.70	39.07	12.96	3.56		2,006	7 (+3)	2026	50
11	TAR6	1.48	0.46	0.25	1.43	4.43	10.92	30.50	30.50	30.50	30.50	18.47	5.09		1,083	5 (+3)	2024	50
12	GN10	2.13	1.90	0.83	0.38	0.70	7.62	16.84	24.40	24.40	[illegible]	16.19	7.43		2,983	7 (+3)	2026	50
13	DN12	1.44	0.45	0.25	1.39	4.30	10.62	30.78	44.80	44.80	44.80	17.95	4.95		1,634	7 (+3)	2026	50
14	MAD5	16.79	11.84	6.81	4.92	8.51	10.51	27.70	28.90	28.90	28.90	28.90	26.09		3,592	7 (+3)	2026	50
13	DON4	3.08	0.96	0.52	2.95	9.18	22.64	55.70	55.70	55.70	55.70	38.29	10.56		2,430	5 (+3)	2024	50
14	DN11	1.11	0.35	0.19	1.06	3.29	8.13	20.33	20.33	20.33	20.33	13.74	3.79		2,010	5 (+3)	2024	50

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2.5 Fuel price, availability and reserve
2.6 Power development policy

- Gas price, gas allocation to power generation and natural gas reserve will be updated by GACN and NGC.
- Any change in power development policy such as the promotion of renewable energy, coal fired power and nuclear power shall be incorporated into the revision of power development plan.

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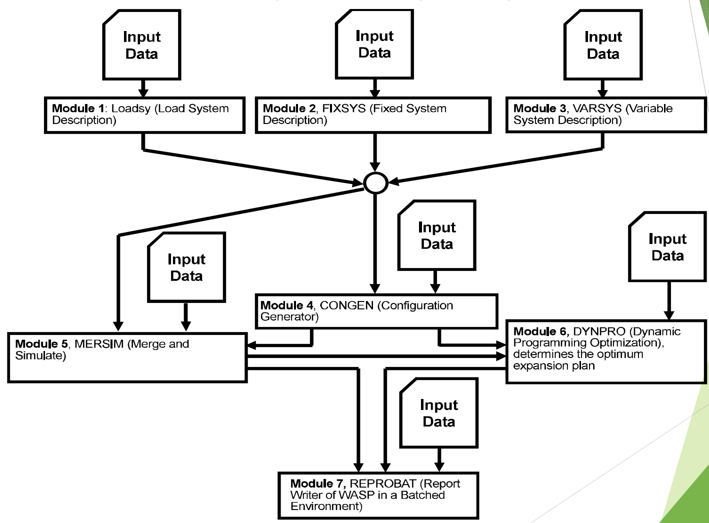
3. WASP simulation

- Updated data will be used for WASP simulation to obtain the revised least cost generation expansion plan.



Source: WASP IV User's Manual

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Function of WASP modules

- Module 1: Loadsy (Load System Description), processes information describing period peak loads and load duration curves for the power system over the study period.
- Module 2, FIXSYS (Fixed System Description), processes information describing the existing generation system and any predetermined additions or retirements, as well as information on any constraints imposed by the user on environmental emissions, fuel availability or electricity generation by some plants.
- Module 3, VARSYS (Variable System Description), processes information describing the various generating plants which are to be considered as candidates for expanding the generation system.
- Module 4, CONGEN (Configuration Generator), calculates all possible year-to-year combinations of expansion candidate additions which satisfy certain input constraints and which in combination with the fixed system can satisfy the loads. CONGEN also calculates the basic economic loading order of the combined list of FIXSYS and VARSYS plants.
- Module 5, MERSIM (Merge and Simulate), considers all configurations put forward by CONGEN and uses probabilistic simulation of system operation to calculate the associated production costs, energy-not-served and system reliability for each configuration. In the process, any limitations imposed on some groups of plants for their environmental emissions, fuel availability or electricity generation are also taken into account. The dispatching of plants is determined in such a way that plant availability, maintenance requirement, spinning reserve requirements and all the group-limitations are satisfied with minimum cost. MERSIM can also be used to simulate the system operation for the best solution provided by the current DYNPRO run and in this mode of operation is called REMERSIM.
- Module 6, DYNPRO (Dynamic Programming Optimization), determines the optimum expansion plan based on previously derived operating costs along with input information on capital costs, energy-not-served cost and economic parameters and reliability criteria.
- Module 7, REPROBAT (Report Writer of WASP in a Batched Environment), writes a report summarizing the total or partial results for the optimum or near optimum power system expansion plan and for fixed expansion schedules.

4. Update of generation expansion plan
4.1 Evaluation of generation expansion scenarios

- Generation expansion scenarios as shown in the following table will be compared and evaluated from the aspects of cost (total generation cost), energy balance (sustainability and security of energy resources) and environment (amount of emission). If necessary, generation expansion scenarios will be modified or added.

	Capacity Share			Evaluation		
	Gas	Coal	Hydro and Renewable	Cost	Energy Balance	Environment
Scenario-1 (Conservative)	70%	10%	20%			
Scenario-2 (More coal)	60%	20%	20%			
Scenario-3 (No coal)	75%	0%	25%			

4.2 Formulation of revised generation expansion plan

- The revised WASP simulation results indicate the updated least cost generation expansion plan. However, variable expansion candidates for thermal power plants do not have the information on their location and connection points to the grid.
- Therefore, they need to be allocated to specific projects which are included in IPP queue lists so that all the sites for expansion candidates are identified. This is necessary for power system analysis which follows the generation expansion plan.

MASTER PLAN STUDY ON NATIONAL POWER SYSTEM DEVELOPMENT
IN THE FEDERAL REPUBLIC OF NIGERIA

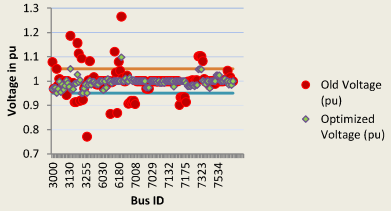
TWG on
Transmission System Analysis

Feb 2017

By Engr. Nazif Abdulkadir
Sudipto Bhowmik

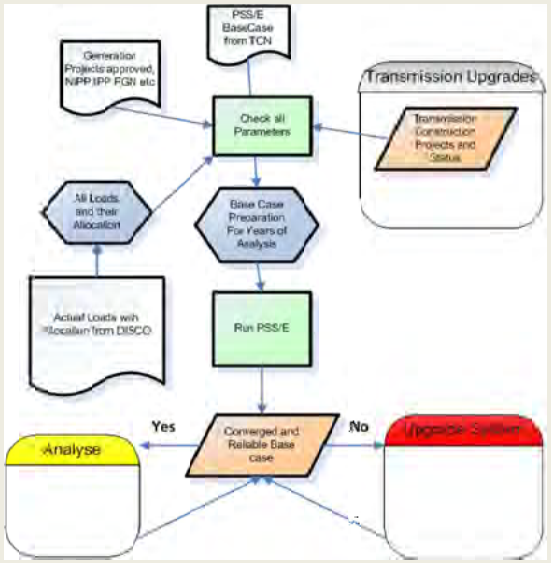
Overview

- Long term planning study
- Analysis consists of Steady state analysis
  - i. Powerflow
  - ii. Contingency analysis
  - iii. Reactive Study



- Cost based analysis and alternative Voltage Levels

Overall Process flowchart



Transmission System update procedure

Creation of starting year Base case

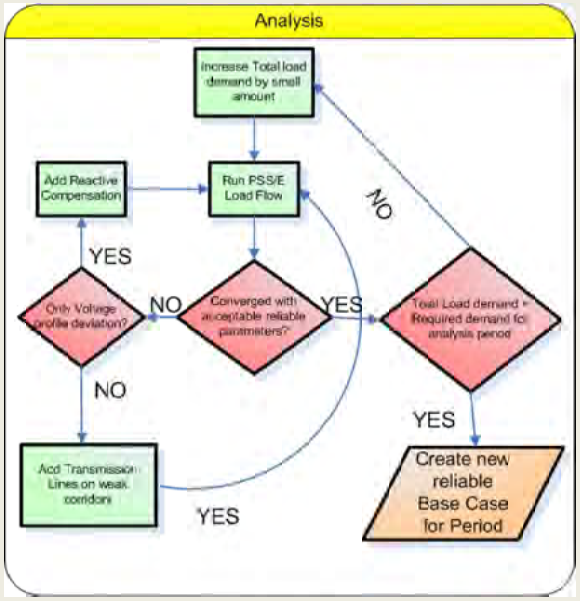
- Run preliminary power flow
- Check values and parameters

– **Transmission Upgrades**
  - Include the transmission upgrades scheduled by TCN and NIPP till year end for the year of analysis
  - Take into account risks such as legal or financial for calculating actual date of completion
  - Include the locations and type of conductor or transformers in the base case

– **Generation Upgrades**
  - Amount and location of new Generation for the year of analysis
  - Include all technical and financial constraints as risks for compleation of the final online status of the generation
  - Include the assumption that generation will participate in regulation by 10% of available capacity

– **Load Upgrades**
  - Amount and location of new Load for the year of analysis
  - Use the actual data collected from the DISCOS and their estimated load increase
  - Proportional load allocation to be included at all load buses

Analysis Process



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Technical Analysis procedure:

– Incremental increase in Load at all buses

- Run power flow for convergence
- Check results for indication of voltage or convergence failure

– Voltage profile analysis

- Check values of voltages at all buses and ensure they fall within limits
- Adjust by adding reactive compensation

– Steady state convergence analysis

- Check flows and whether they fall within limits of lines and transformer ratings
- Adjust by adding transmission lines and or upgrading transformers

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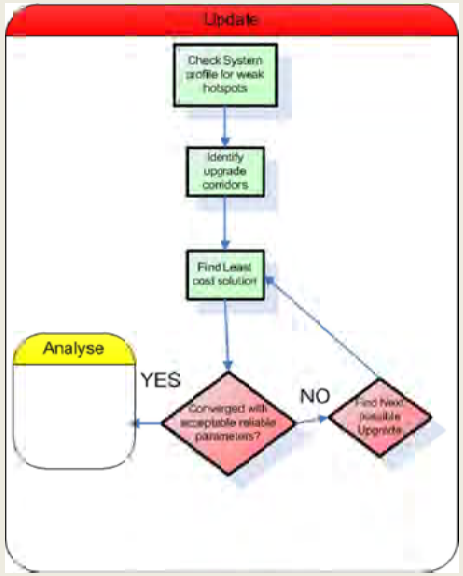
Upgrading of System



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Upgrade system procedure:

– Include scheduled system upgrades

- Include transmission upgrades
- Include transformer upgrades
- Include substation upgrades

– Incremental system upgrades

- For convergence create set of transmission upgrades based on weak corridors
- Create viable sets based on incremental mitigation by including the upgrades

– Cost analysis

- Perform cost based analysis of all set of viable transmission upgrades
- Check viability of different technology such has higher voltages

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