# Ethiopian Electric Power Corporation (EEPCO).

Ethiopian Power System Expansion Master Plan update (EPSEMPU).

June 2006

# OUTLINE

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III. PLANNING METHODOLOGY AND CRITERIA
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# BACKGROUND

# The Energy Sector.

- The National energy policy emphasized the need for equitable distribution of electricity in all regions in support of the nations socio economic development.

- The policy envisages the development of  hydro, geothermal, natural gas, coal, wind and solar energy resources based on their economic viability, social and environmental acceptability.

# The Electric Power Sector.

- Ethiopia's electric power supply system is operated by the Ethiopian Electric Power Corporation (EEPCO), which is owned by the Ethiopian Government.

- EEPCO is responsible for generation, transmission, distribution and sales of electricity nationwide.

- The role of the power sector in the economic recovery endeavor of the nation is required to be leading and vital.However it’s role remains to be quite low compared to the contribution expected from it.

# The Electric Power Sector Ctd.

- As has been the case during recent years, the demand for electricity is expected to grow sharply as a result of the liberalized economic policy .
- The policy will necessarily generate new and widely dispersed centers of high demand for power in industrial zones, in the real estate development communities and also in and around new rural towns and village communities.

# The Electric Power Sector Ctd…

- Despite all these, the power sector is in a poor state to be able to meet the service demanded by the growing economy and the inevitable access expansion.

- The sector is to face shortage of generation capacity in the near future warranting urgent attention which otherwise could be an impeding factor to the overall national development program.

- **THE EXISTING POWER SYSTEM**

# Existing System

- EEPCO operates two power supply systems, namely the main interconnected system (ICS) and the self-contained system (SCS).
- The main ICS, which serves the major towns and industrial centers, has a total installed capacity of 760.3MW and a firm energy generation capacity of 3088 Gwh/yr.

# Existing System ctd.

- This generation capacity is contributed by hydropower plants having a total installed capacity/Firm energy generation capacity of 671 MW/2600Gwh/yr and thermal stations with capacity of about 89 MW/488Gwh/yr.

- The thermal stations are stand-by diesel stations at different places including emergency diesel units at Kaliti (14 MW), Awash Town (35 MW) and Dire Dawa (40 MW), which are required to mitigate the power shortage during seasonal influence on the hydro reservoirs.

# Existing System ctd

- The SCS supplies isolated load centers, which are far from the ICS, mostly using diesel plants as a source of generation.
- Currently this system has an aggregate installed capacity of about 20 MW, of which 70 percent, i.e.. 13.8 MW is being generated from diesel stations.
- The remaining balance of 6.2 MW is being generated from small hydro power plants located at Sor, Yadot and Dembi.

# Existing System ctd

- The existing power transmission network consists of about 1715 KM of 230 kV,2561 KM of 132 kV 1782 KM of 66 kV and 476 KM of 45Kv lines.
- At present the reach of the transmission line is limited to the central part of the country following the main roads connecting major cities.
- EEPCO currently provides electricity to a total of about 934,000 customers in approximately 632 towns and communities in Ethiopia,

# Existing System ctd

- According to current estimates only about 15% of the population has access to electricity. The government has launched a universal electricity access program to be executed by EEPCO with the view to enhance the access to 50%.

- Out of the total number of customers 95% are supplied from the ICS and the remaining 5% are within the SCS.

- POWER DEMAND FORECAST

# Power Demand Forecast

## Methods of Forecast Analysis

- Times Series
- Econometric
- End-Use
- Input-Output

- EEPCO at present uses an Econometric Model.
- Rural Electrification is separately included as an adjustment to the econometric model output.

## Power Demand Forecast Cntd.

- Three separate models, which capture consumption growth variability in different branches of the interconnected system were identified. These are:

  - MODEL 1     BASE ICS
  - MODEL 2     INITIAL EXTENSIONS
  - MODEL 3     RECENT EXTENSIONS

## Power Demand Forecast Cntd.

- The forecast is prepared for the following consumption categories :

- DOMESTIC
- COMMERCIAL
- INDUSTRIAL

## Power Demand Forecast Cntd.

A number of independent variables were evaluated through extensive regression analysis. Out of these, the following three were found to have significant effect on the electricity consumption.

- 1 Non Agricultural GDP
- 2 Price
- 3 NUMBER OF CUSTUMERS

## Power Demand Forecast Cntd.

- The regression analysis performed further resulted into the following elasticity figures for the three models and each customer category :

**DOMESTIC**

| | MODEL 1 | MODEL 2 | MODEL 3 |
|---|---|---|---|
| INCOME | 0.35 | 0.60 | 0.80 |
| PRICE | -0.40 | -0.50 | -0.60 |

**COMMERCIAL**

| | MODEL 1 | MODEL 2 | MODEL 3 |
|---|---|---|---|
| INCOME | 0.60 | 0.60 | 1.20 |
| PRICE | -0.20 | -0.20 | -0.35 |

**INDUSTRIAL**

| | MODEL 1 | MODEL 2 | MODEL 3 |
|---|---|---|---|
| INCOME | 0.90 | 0.90 | 1.20 |

## Power Demand Forecast Cntd.

- The following assumptions were taken for the growth rates of the independent variables:
  - **GDP;** The current good economic performance is expected to continue in the future. Based on this, a 12 % annual growth is taken for the Target Scenario, while an 8% GDP growth is assumed for the Moderate Scenario.
  - **PRICE:** **P**rice adjustment which will bring the current real price to that of the 1998 level is considered. This results into a 16 % increment and is assumed to be implemented in year 2007.

## Power Demand Forecast Cntd.

- Number of Customers:
  - recently there is a high customers turnout. Last fiscal year alone the ICS has incorporated more than 114,000 customer excluding the additions due to rural electrification.
  - These year more than 150,000 new customers are expected to connect in the already electrified towns.
  - These number when divided into the three models and translated into growth rates results into the following:
  - model 1:-12.7 % for domestic, 17.2 % for commercial
  - model 2:- 22 % for domestic, 9.4% for commercial
  - model 3: 25.5 % for domestic, 12.3 %for commercial
  - these growth rates are expected to decline to population growth rates within 10 years.

# Rural Electrification:

- EEPCO is undertaking huge electrification program to increase the present low rate of electricity access.
- The assumption taken here is that the target of increasing the present electricity access to 50 % will be achieved within 5 years.
- A separate forecast for the electrification of around 24 million population within five years is augmented therefore on the result of the econometric model described above.

## Expected Generation & Peak Load

- The forecasts will first be prepared as consumption forecasts.
- Once the total consumption figure is found it will be converted to Generation figure using loss rate assumptions.
  - Considering the ongoing distribution system rehabilitations, a loss rater which decreases from the recent three years average of 18.6% to 15% reducing every year by  0.5 percentage points is applied.
- The Energy Generation figure thus is converted to Peak demand value using again three years average load factor of 57%.

# Power Demand Forecast Cntd.

The result of the Forecast are presented below.

**Target Scenario**

| Year EFY | Dom. (MWh) | Com. (MWh) | Str. Lig. (MWh) | Industrial LV (MWh) | HV (MWh) | Total (MWh) | Rural Electrif. (MWh) | Total Sales (MWh) | Losses (MWh) | Gen. (Fiscal Cal.) (MWh) | % Grh | Peak Fiscal Cal (MW) | % Grh | Loss Rate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | 704,583 | 507,709 | 28,350 | 401,463 | 386,832 | 2,028,938 | | 2,028,938 | 520,187 | 2,534,710 | | 520 | 3.43% | 20.0% |
| 2006 | 870,850 | 639,406 | 27,690 | 448,928 | 428,734 | 2,415,609 | 126,059 | 2,541,669 | 582,765 | 3,122,089 | 23.17% | 625 | 20.17% | 18.6% |
| 2007 | 986,464 | 764,581 | 31,847 | 501,329 | 481,718 | 2,765,940 | 277,772 | 3,043,711 | 675,449 | 3,715,957 | 19.02% | 744 | 19.02% | 18.1% |
| 2008 | 1,178,592 | 929,118 | 37,556 | 559,678 | 541,403 | 3,246,347 | 459,254 | 3,705,601 | 778,100 | 4,496,585 | 21.01% | 900 | 21.01% | 17.6% |
| 2009 | 1,395,764 | 1,119,074 | 44,122 | 625,329 | 608,656 | 3,792,945 | 675,250 | 4,468,195 | 894,575 | 5,389,261 | 19.85% | 1,079 | 19.85% | 17.1% |
| 2010 | 1,645,858 | 1,341,589 | 51,873 | 703,150 | 685,489 | 4,427,959 | 931,221 | 5,359,181 | 1,029,943 | 6,425,166 | 19.22% | 1,286 | 19.22% | 16.6% |
| 2011 | 1,904,925 | 1,579,335 | 60,065 | 785,643 | 771,103 | 5,101,071 | 1,122,121 | 6,223,192 | 1,172,813 | 7,416,576 | 15.43% | 1,485 | 15.43% | 16.1% |
| 2012 | 2,185,087 | 1,844,468 | 69,172 | 878,012 | 867,660 | 5,844,399 | 1,343,875 | 7,188,274 | 1,330,690 | 8,515,981 | 14.82% | 1,705 | 14.82% | 15.6% |
| 2013 | 2,486,348 | 2,139,502 | 79,268 | 981,467 | 976,589 | 6,663,173 | 1,601,189 | 8,264,363 | 1,504,821 | 9,733,174 | 14.29% | 1,949 | 14.29% | 15.1% |
| 2014 | 2,808,878 | 2,467,433 | 90,440 | 1,097,366 | 1,099,510 | 7,563,629 | 1,899,472 | 9,463,101 | 1,704,724 | 11,133,060 | 14.38% | 2,229 | 14.38% | 15.0% |
| 2015 | 3,153,069 | 2,831,797 | 102,794 | 1,227,242 | 1,238,261 | 8,553,163 | 2,244,952 | 10,798,116 | 1,927,924 | 12,703,665 | 14.11% | 2,544 | 14.11% | 15.0% |
| 2016 | 3,519,560 | 3,236,742 | 116,448 | 1,372,818 | 1,394,925 | 9,640,494 | 2,644,785 | 12,285,279 | 2,175,003 | 14,453,269 | 13.77% | 2,894 | 13.77% | 15.0% |

**Growth Rates**

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 05-16 | 16% | 18% | 14% | 12% | 12% | 15% | | 18% | 14% | 17% | | 17% | 13% | |

# Power Demand Forecast Cntd.

## Forecast Results Ctd..

| Year EFY | Dom. (MWh) | Com. (MWh) | Str. Lig. (MWh) | Industrial LV (MWh) | Industrial HV (MWh) | Industrial Total (MWh) | Rural Electrif. (MWh) | Total Sales (MWh) | Losses (MWh) | Gen. (Fiscal Cal.) (MWh) | % Grh | Peak Fiscal Cal (MW) | % Grh | Loss Rate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Moderate Scenario** | | | | | | | | | | | | | | |
| 2005 | 704,583 | 507,709 | 28,350 | 401,463 | 386,832 | 2,028,938 | | 2,028,938 | 520,187 | 2,534,710 | | 520 | 3.43% | 20.0% |
| 2006 | 852,209 | 618,673 | 26,740 | 429,678 | 409,271 | 2,336,570 | 126,059 | 2,462,629 | 582,765 | 3,025,000 | 19.34% | 606 | 16.44% | 18.6% |
| 2007 | 944,229 | 716,061 | 29,711 | 460,442 | 439,144 | 2,589,586 | 277,772 | 2,867,358 | 675,449 | 3,500,654 | 15.72% | 701 | 15.72% | 18.1% |
| 2008 | 1,102,263 | 841,750 | 33,852 | 493,114 | 471,215 | 2,942,193 | 459,254 | 3,401,447 | 778,100 | 4,127,508 | 17.91% | 826 | 17.91% | 17.6% |
| 2009 | 1,274,595 | 980,493 | 38,426 | 528,398 | 505,620 | 3,327,532 | 675,250 | 4,002,782 | 894,575 | 4,827,909 | 16.97% | 967 | 16.97% | 17.1% |
| 2010 | 1,465,437 | 1,134,763 | 43,601 | 569,256 | 543,388 | 3,756,444 | 931,221 | 4,687,666 | 1,029,943 | 5,620,081 | 16.41% | 1,125 | 16.41% | 16.6% |
| 2011 | 1,653,510 | 1,289,745 | 48,728 | 609,595 | 583,210 | 4,184,788 | 1,122,121 | 5,306,909 | 1,172,813 | 6,324,584 | 12.54% | 1,266 | 12.53% | 16.1% |
| 2012 | 1,848,119 | 1,453,290 | 54,137 | 652,802 | 626,024 | 4,634,371 | 1,343,875 | 5,978,246 | 1,330,690 | 7,082,456 | 11.98% | 1,418 | 11.98% | 15.6% |
| 2013 | 2,048,136 | 1,625,288 | 59,817 | 699,081 | 672,060 | 5,104,382 | 1,601,189 | 6,705,571 | 1,504,821 | 7,897,341 | 11.51% | 1,581 | 11.51% | 15.1% |
| 2014 | 2,252,632 | 1,805,778 | 65,766 | 748,650 | 721,568 | 5,594,394 | 1,899,472 | 7,493,866 | 1,704,724 | 8,816,313 | 11.64% | 1,765 | 11.64% | 15.0% |
| 2015 | 2,460,886 | 1,994,947 | 71,985 | 801,745 | 774,815 | 6,104,379 | 2,244,952 | 8,349,331 | 1,927,924 | 9,822,743 | 11.42% | 1,967 | 11.42% | 15.0% |
| 2016 | 2,672,389 | 2,193,129 | 78,480 | 858,618 | 832,090 | 6,634,706 | 2,644,785 | 9,279,491 | 2,175,003 | 10,917,048 | 11.14% | 2,186 | 11.14% | 15.0% |
| **Growth Rates** | | | | | | | | | | | | | | |
| 05-16 | 13% | 14% | 10% | 7% | 7% | 11% | | 15% | 14% | 14% | | 14% | 11% | |

- PLANNING METHODOLOGY AND CRITERIA

# Generation planning Methodology

- Power system planning involves a number of interrelated activities, all of which depend on the others for consistent analytical input data and results. These activities can sometimes be carried out either in parallel or iteratively.
- Usually a tentative generation expansion plan is prepared first. The transmission expansion requirements are then determined to ensure that sufficient transmission capability is in place to transmit the generated power throughout the interconnected grid system.

# Generation planning Methodology ctd

- These transmission requirements are then added into the generation plan to include all the major investment requirements for each of the alternative system expansion options. Finally, the complete power system expansion plan can be refined to determine the overall cost effective system development plan.

# Transmission planning Methodology

- The starting point for the transmission system expansion plan is a review of the updated load forecast as distributed to the grid substations and the proposed generation expansion plan.
- The load and generation resources are grouped into 8 load/generation areas and the areas' net balance of generation and load is determined for a series of years.
- The power flow in the lines connecting these areas was estimated, and these flows indicated where transmission reinforcements would be needed as well as their timing

# Transmission planning Methodology ctd

- Detailed load flow, short circuit and stability studies are carried out for selected years, which, in general, coincided with major generation additions.

- The purpose of these studies is to provide information on the loading of individual circuits, identify the need for reactive compensation and to determine the general overall system performance under a variety of operating conditions.

# Planning Criteria

- The Planning Time Frame
- Economic Criteria
  - Cost datum
  - Foreign exchange rate & shadow prices
  - Discount rate
  - Thermal fuel costs
  - Economic cost of unserved energy
  - Social & environmental costs

# Planning Criteria ctd..

- Reliability Criteria
  - Hydrologic reliability
  - Bulk generation system reliability
- Technical Criteria
  - Transmission system planning criteria

# The Planning Time Frame

- Planning Horizon: 2006 to 2030
- Sales Statistics & Demand Forecast: EPCO Fiscal Year
- Hydrologic Year similar to Gregorian Calendar Year
- Planning Simulation based on Gregorian Calendar Year

## Foreign Exchange Rate, Shadow Prices, Opportunity cost of capital and Cost of unserved energy.

- Standard Conversion Factor (SCF) for Local Costs: 0.90
- 8.74 birr per US Dollar (January 2006)
- Real Discount Rate 10%
- Sensitivity 9% to 15%
- Cost of Unserved energy: 0.52$/Kwh

# Hydrologic and Bulk Generation System Reliability Criteria.

- Firm Hydro System Energy is defined on the basis of 1 month Failure to meet Demand in 37 years of Hydrologic Record.
- This is equivalent to 98.4% hydrologic Reliability (when the system is operated in accordance with the recommended policy)
- Maximum LOLE of 10 days/yr under critical drought conditions.

# Transmission Planning Criteria

- Bus Voltages
  - Normal ± 5% of Nominal
  - Emergency + 5%, -10% of Nominal
- Equipment Loading
  - Normal 100% of Long-Term Rating
  - Emergency 20% Short-Term Overload
- System Contingencies
  - Supply all loads within Emergency Limits with any single equipment outage (N-1 Criterion)
- Network Stability
  - Maintain synchronism with 3-phase fault and successful reclosure

- **Generation Resources**

# Committed and Planned Generation Projects

| Plant | Capacity | Firm Energy | Average Energy | Status |
|---|---|---|---|---|
| Tekeze | 300 | 964 | 1069 | U.construction |
| Gilge Ghibe II | 420 | 1504.0 | 1903.0 | U.construction |
| Beles | 420 | 1842 | 1842 | U.construction |
| GGIII (Phase I) | 900 | 3150 | 3150 | Candidate |
| GGIII (Phase II) | 900 | 3150 | 3150 | Candidate |
| Halele | 96 | 377 | 429 | Candidate |
| Werebesa | 339 | 1653 | 1804 | Candidate |
| Halele+Worabesa | 435 | 2030 | 2233 | Candidate |
| Chemoga Yeda 1 | 118 | 534 | 526 | Candidate |
| Chemoga Yeda 2 | 89 | 342 | 429 | Candidate |
| Chemoga Yeda 1&2 | 207 | 876 | 955 | Candidate |
| Yayu Coal | 100 | 700.8 | 700.8 | Committed |
| Genale 2 | 171 | 552 | 613 | Candidate |
| Genale3 | 177 | 1147 | 1183 | Candidate |
| Genale 2&3 | 348 | 1699 | 1796 | Candidate |
| Geba 1 | 194 | 882.6 | 935.1 | Candidate |
| Geba 2 | 150 | 797.4 | 852.9 | Candidate |
| Geba 1&2 | 344 | 1680 | 1788 | Candidate |
| Aleltu West | 265 | 981 | 1051 | Candidate |
| Baro1 | 166 | 464 | 727 | Candidate |
| Baro2 | 479 | 1288 | 2059 | Candidate |
| Baro 1&2 | 645 | 1752 | 2786 | Candidate |
| Aleltu East Stage 1 | 189 | 631 | 657 | Candidate |
| Calub (CCGT)-Natgas | 600 | 4204.8 | 4204.8 | Candidate |
| Caradobi | 1800 | 8900 | 8900 | Candidate |
| Tendaho Geothermal | 30 | 220 | 220 | Candidate |
| Aluto Geothermal | 10 | 75 | 75 | Candidate |

# Unit cost of attractive generation project

| PowerPlant | Average Energy(GWH) | Estimated unit energy cost($/Kwh) |
|---|---|---|
| Beles | 2142 | 0.0285 |
| Gilgel Gibe III | 6300 | 0.0339 |
| Gilgel Gibe II | 1903 | 0.0269 |
| Halele Werabessa | 2233 | 0.0311 |
| Geba1&2 | 1788 | 0.0313 |
| Chemoga yeda 1&2 | 1391 | 0.0367 |

- Preliminary Planning Analyses

Indicated System Needs

# Committed generation projects and Supply-Demand balance.

- Beginning in 2008, the Tekeze and Gilgel Gibe II hydro projects are expected to be in hand and in addition Beles & Yayu coal plants are sought to be on line by 2009 and 2010 respectively.
- Once this projects are completed, the projected ‘demand-supply’ balance is expected to be as shown in the following two slides, one with own demand and the other  with export demand of Sudan and Djibouti as pointed out in the respective feasibility studies of interconnection.

# Projected Supply and Demand Balance-Own Demand

| | Short Term (To 2009) | | Medium Term (To 2011) | | Medium term (To 2013) | | Medium Term (To 2016) | |
|---|---|---|---|---|---|---|---|---|
| | **Energy** (GW.h) | **Power** (Mw) | **Energy** (GW.h) | **Power** (Mw) | **Energy** (GW.h) | **Power** (Mw) | **Energy** (GW.h) | **Power** (Mw) |
| Forecast Demand | | | | | | | | |
| Target scenario | 5708 | 1360 | 7856 | 1920 | 10309 | 2456 | 15309 | 3039 |
| Moderate scenario | 5041 | 1201 | 6603 | 1573 | 8245 | 1964 | 11398 | 2715 |
| Existing and Committed supply capability | 6600 | 1794 | 7301 | 1894 | 7301 | 1894 | 7301 | 1894 |
| Projected needs | | | | | | | | |
| Target scenario | Nil | Nil | 555 | 26 | 3008 | 562 | 8008 | 1145 |

New plant rquired

# Projected Supply and Demand Balance- With Export Demand of Sudan & Djibouti.

| | Short Term (To 2009) | | Medium Term (To 2011) | | Medium term (To 2013) | | Medium Term (To 2016) | |
|---|---|---|---|---|---|---|---|---|
| | **Energy** (GW.h) | **Power** (Mw) | **Energy** (GW.h) | **Power** (Mw) | **Energy** (GW.h) | **Power** (Mw) | **Energy** (GW.h) | **Power** (Mw) |
| Forecast Demand | | | | | | | | |
| Target scenario | 6509 | 1610 | 9958 | 2220 | 12442 | 2756 | 17411 | 3039 |
| Moderate scenario | 5842 | 1445 | 8706 | 1873 | 10348 | 2264 | 13500 | 3015 |
| Existing and Committed supply capability | 6600 | 1794 | 7301 | 1894 | 7301 | 1894 | 7301 | 1894 |
| Projected needs | | | | | | | | |
| Target scenario | Nil | Nil | 2657 | 326 | 5141 | 862 | 10110 | 2053 |

New plant rquired

# Projected Supply and Demand Balance Ctd..

- As seen from the preceding two slides, starting at year 2011 there is a deficit requiring the incorporation of an additional plant(s).The updated generation expansion plan would constitute Giggle Gibe III phase I&II , Hallele Worabesa and Chemoga yeda hydro projects respectively to be incorporated to the ICS by 2011,2012 2015 and 2016 respectively to meet the projected own demand.

- These projects would be required by 2011, 2012 2014 and 2015 respectively when considering the export demand of Sudan and Djibouti estimated in the respective interconnection feasibility studies. However the export demand could go higher than that presented in these studies as the estimate was based on the expected surplus hydro energy during the study period, which was a function of the proposed generation expansion plan at that time

# Updated Generation Expansion Plan Summary

| Year OnLine | Addition | No | x | MW | System Dependable Capacity MW | Capital Cost Generation $ Million | Capital Cost Transmission $ Million |
|---|---|---|---|---|---|---|---|
| Existing | | | | | 726 | | |
| 2007 | Aluto langano re | 2 | x | 3.5 | 733 | | |
| 2008 | Gilgel Gibe II | 4 | x | 105 | 1153 | 451.3 | 51.0 |
| 2008 | Tekeze** | 4 | x | 75 | 1453 | - | - |
| 2009 | Beles | 4 | x | 115 | 2243 | 500 | 117.0 |
| 2010 | Yayu Coal | 2 | x | 50 | 1973 | 175.3 | 26.0 |
| 2011 | GGIII (Phase 1) | 5 | x | 180 | 2873 | 957.3 | |
| 2012 | GGIII (Phase 2) | 5 | x | 180 | 3773 | 410.3 | 143.6 |
| 2014 | Hallele Worabessa | 2 | x | 48.5 | | | |
| | | 4 | x | 81.5 | 4195 | 474.0 | 24.5 |
| 2015 | Chemoga Yeda | 2 | x | 81 | | | |
| | | 2 | x | 59 | 4475 | 391.2 | 8.45 |

**PWC** **2006-2015** **1321MUSD**

# Transmission Planning

# Transmission Planning

## Analysis Types:

- Load Flows
  - to determine satisfactory performance under normal and emergency conditions
- Stability Analysis
  - to determine satisfactory response and stable operation in the event of sudden disturbances (e.g. transmission line faults, generator outages)
- Fault Studies
  - to ensure equipment ratings required to protect the system under fault conditions

# Transmission Planning Ctnd.

- The analysis made on the HV network is focused on the voltage levels of 132kV and above. New transmission needs are generally four types:
  - to reinforce the existing high voltage (H-V) grid-system to growing load centers
  - to connect new generation projects to the nearest H-V power grid-system point
  - to reinforce the H-V power grid-system beyond new generation connection points to be able to carry the augmented supply beyond these points
  - to extend the H-V power-grid system to isolated demand centers which have grown sufficiently to make such extension more economic than continued local generation

# Transmission Planning Ctnd.

- Critical periods (2008, 2009, 2011, 2014 and 2015), which coincides with generation additions are selected for the analysis.

- For these periods peak load conditions which indicate possible overload as well as under voltages situations are analyzed. This has helped in identifying transformer additions, line reinforcements and capacitive reactor requirements.

- Light load conditions were also run to identify and remedy over voltage situations with installations of shunt reactors.

- In order to satisfy the N-1 criterion, contingency analysis which simulate and assure the effective performance of the system during the outage of critical system components has been undertaken .

# Transmission Planning Ctnd.

- The results of the analysis revealed that, within the planning Horizon about 6800 km of additional HV lines comprising of 400, 230, 132kV voltage levels will be required.
- Out of these lines 2200 km are related to generation interconnections, 4000 are related to planned expansion to new areas and the balance 600 are related to reinforcements.

# Transmission Planning Ctnd.

- Around 47 new substations have to be constructed.

- In order to cope with the anticipated target forecast growths additional transformers with a total magnitude of 3500 MVA, capacitive reactors of about 680 Mvar have to be installed at various locations in the system.

- As Addis Ababa is the largest load center, it takes 70% of the above transformer installations and 60% of the capacitive reactor installations.

# International Interconnection

National Electricity Corporation, Sudan (NEC)

Electricite de Djibouti (EdD)

Ethiopian Electric Power Corporation (EEPCo)

The Kenya Power & Lighting Co. Ltd.

# 1. General

- Ethiopia is focusing on the development of the huge hydro potential it possesses in the Eastern African Region.
- To get the required economy of scale to develop the extra-big hydropower sites in Ethiopia, it is compulsory to seek foreign demands for export purposes, especially, neighboring countries of Sudan, Egypt, Djibouti, Yemen, Kenya, Eritrea, and Somalia.
- Hence, Ethiopia should widen and deepen her cooperation with the neighboring countries in the political, economic, and social fields for the mutual benefits of all the population in the Region through integrated development of their power systems and interconnection links to effect cross-border electricity trading.

# General /Contd./

- Regional infra-structure development co-operations especially power interconnection projects are in conformity with the interests of international financiers (WB, AfDB, EIB, etc.) and with the objectives of NePAD.

- The EPSEMPU document, thus, addressees the power interconnection issue with neighboring countries to meet the future demands for electric energy in these countries from environmentally friendly and cheap hydro energy of Ethiopia.

# 2. Expected Energy for Export

- **Excess energy available in Ethiopia for the Target Forecast (in GWh)-(2006-2016)**

| | Minimum | Average | Maximum |
|---|---|---|---|
| Hydro-*Firm* | 0 | 1606 | 4200 |
| Hydro-*Secondary* | 0 | 682 | 1038 |
| Thermal | 0 | 877 | 1228 |
| Total | 0 | 3165 | 6159 |

# Expected Energy for Export /Contd./

- **Excess energy available in Ethiopia for the Moderate Forecast (in GWh)-(2006-2016)**

| | Minimum | Average | Maximum |
|---|---|---|---|
| Hydro-*Firm* | 0 | 2422 | 5825 |
| Hydro-*Secondary* | 0 | 598 | 731 |
| Thermal | 0 | 883 | 1228 |
| Total | 0 | 3903 | 7784 |

# 3. Potential Interconnections

- ***Ethiopia-Sudan***
  - Currently, the export will be based on surplus-firm and non-firm (secondary) energy.
  - A link of double circuit 230 kV with transfer capacity of about 200 MW is proposed.
  - It will be under implementation stage very soon and be in-service in February 2008.
  - The link starts from Bahir Dar substation passing through Gonder and Shehedi substations in Ethiopia and ends at Gedaref substation in Sudan with a total length of 296 km.
- ***Ethiopia-Djibouti***
  - Here also, the export will be based on surplus-firm and non-firm (secondary) energy.
  - A link of single circuit 230 kV with transfer capacity of about 100 MW is proposed.
  - This link will create an opportunity for Ethiopia to export energy to Yemenis  market through undersea cable of 26 km 230 kV line.

# Potential Interconnections /Contd./

- It will be under design and tendering stage very soon and be in-service in June 2010.
- The link starts from Dire Dawa substation in Ethiopia and ends at PK-12 substation in Djibouti with a total length of 283 km.

- ***Ethiopia-Kenya***
  - The export will, possibly, be based on firm energy.
  - The link may start from Giggle Gibe-III power plant and passes through Mega substation in Ethiopia and ends at the towns of Nairobi or Eldorate in Kenya.
  - The link from Giggle Gibe-III to Mega might be double circuit 400 kV HVAC. HVDC link of at least 500 kV with transfer capacity of about 600 MW is anticipated from Mega substation to Kenya (Nairobi or Eldorate).
  - It will be under study stage very soon and the in-service year is anticipated in 2011 with Giggle Gibe-III.

# Potential Interconnections /Contd./

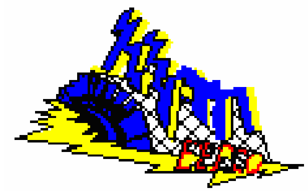
- ***Ethiopia-Somaliland***
  - A link of single circuit 230 kV with transfer capacity of about 50 MW is anticipated.
  - The link will start from Dire Dawa substation in Ethiopia and ends at the towns of Hargessa and Berbera in Somaliland with a total length of 445 km.
  - It is under initial stage of development.
- ***Ethiopia-Eritrea***
  - The East-West 230 kV project from Tekeze to Humera will establish a substation at Shire Inda-Selasie which could be the interconnection point in Ethiopia.
  - Thus, the link may start from Shire Inda-Selasie substation in Ethiopia and ends at the town of Asmara in Eritrea with a total length of about 200 km.
  - The current political situation between the two countries may not favor early development

# Potential Interconnections /Contd./

- ***The Egyptian Market***
  - The link with Egyptian grid will open a wider market for Ethiopia as Egypt is interconnected to the west with Libya, Morocco and in the east with Jordan, Syria, and Turkey.
  - Morocco is connected with Spain, thus, Egypt is already in the European grid. Similarly, Turkey will very soon be part of the European grid, which will establish another connection point for Egypt in the European grid.
  - Export to Egypt is associated with the development of the three big hydropower dams and plants in Ethiopia.
    - Karadobi Dam
    - Mendaya Dam
    - Border Dam
  - The interconnection study with Egypt will start soon under ENTRO/PCU

# Potential Interconnections /Contd./

- HVDC link might be the best option from a central converter station, say, at Pawie Town in Ethiopia to Cairo in Egypt. Possible tap of this HVDC line will be made at Khartoum in Sudan, as well.



- **THANK YOU**