REPORT ON ZESCO LOAD SHEDDING

Engineering Institution of Zambia

Technical Experts Team

September 2015

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ACRONYMS

EIZ	Engineering Institution of Zambia
ENSO	El nino Southern Oscillation
IPCC	Inter-Governmental Panel on Climate Change
ITT	Itezhitezhi
LPG	Liquid Petroleum Gas
m.a.s.l.	Meters above sea level
MW	Mega Watt
NOAA	National Oceanic and Atmospheric Administration
ZESCO	ZESCO Ltd
ZRA	Zambezi River Authority

Executive Summary

In the recent past ZESCO, the national electricity utility has heightened load shedding (electricity rationing) throughout the country. The reason for this action has been attributed to insufficient water in the reservoirs at Kariba and itezhitezhi due to "below average" rainfall experienced during the 2014/15 rainy season. The load shedding averages 6-10 hours per day and affects industries, commercial undertakings, offices and domestic customers alike. This has led to a public outcry and anger against the national utility.

This situation has concerned the Engineering Institution of Zambia (EIZ). The EIZ, in keeping with its mandate stipulated in the EIZ Act No. 17 of 2010, on 13th July 2015 constituted a team of experts, to among other things:

1. Investigate the load shedding
2. Recommend immediate measures to reduce load shedding and
3. Recommend long term measures to avoid or minimize load shedding in future under similar circumstances.

The team set out to work immediately and requested that both ZESCO and the Zambezi River Authority (ZRA) supply data that would be used to assess the way the reservoirs at Kariba and Itezhitezhi have been operated from 2011 to 2015. Similarly data was requested to assess how the power plants have performed in the same period. In addition rainfall data was requested for from the Department of Meteorology in order to have an appreciation of the department's interpretation of the rainfall season.

Key among the data requested for were the following:

- Reservoir levels at Kariba, Itezhitezhi and Kafue Gorge Dams on 30th November, 31st December, 31st January, 28th February, 31st March and 30th April, in the years 2011-15.
- Amount of water passed through the spillways for 2011-15
- Firm generation at Kariba (both North and South banks) and Kafue Gorge.
- Load forecast for Zambia
- Operating Rule Curve at Kariba and Itezhitezhi

The data was expeditiously made available and examined. The outcomes could be grouped according to areas as given below:

1. Kafue Gorge dam, Itezhitezhi dam and the Kafue gorge power station were operating normally.
2. Observations at the Kariba complex were as follows:
    a. Low flows during 2014/2015
    b. There was a big spill of 19.98 billion cubic meters for 87 days during 2011
    c. Power Stations on both banks were generating above given threshold set by the ZRA.
    d. Reservoir level was way below the rule curve for the years 2011-15.
    e. Remedial measures were not timely despite early indications of subdued inflows.

The above observations led the team to conclude that both the subdued inflows (2014/15) and the operations at Kariba Complex were the main contributors to the problem of load shedding and needed to be addressed.

The recommendations are classified as short term (0-1 year), medium term (1-3 years, and Long term (>3 years).

In the short term the following is recommended:

1. Customers must be encouraged to switch off non-essential loads such as geysers, hot elements, swimming pool pumps etc.
2. Large industrial plants like the Mines operating Change Houses should switch to Solar Hybrid Geysers.
3. Customers must be encouraged to use energy efficient equipment such as energy efficient lamps. ZESCO should continue with the exercise of distributing free/exchanging with energy efficient lamps.
4. Customers in low density and medium density residential areas should be encouraged to switch to Liquefied Petroleum Gas (LPG) or other suitable gas for cooking.
5. Government should issue a statutory instrument directing that all new housing estates use hybrid solar water geysers for heating

water and that existing households should be given a fixed period to migrate to hybrid solar geysers.

6. The Practice of switching off lights in offices during the day when there is adequate sunshine should be implemented including regular checks to ensure compliance.
7. Further reduction in generation is a must to avoid total shutdown, therefore ZESCO should heed directives from ZRA.
8. ZESCO should conduct energy audits in Industry with the view to encourage energy efficiency e.g. improving power factor.
9. Power Projects under construction must be supported and expedited e.g. Maamba Coal power plant and Itezhitezhi Hydroelectric Power Station.

In the medium term, On-Grid and Off-Grid renewable energy technologies should be exploited as solutions for distributed generation. In particular small hydro, Solar, Biomass, and Bio-gas etc. must be promoted.

1. Solar energy has rapidly emerged as a clear viable option in recent years. Zambia and Southern Africa in general have good solar resource. Solar energy is now cost competitive with traditional sources of power like coal and hydro. It is a clean source of energy. It can be deployed much faster (1-2 years for utility scale power plants) compared to 2-5 years for coal and hydro power plants. South Africa already has several utility scale solar power plants and several other African countries are following suit. Solar also works with hydro very well as a hybrid system. In view of its advantages, Zambia should fast track some utility scale solar power plants.

2. ZESCO should as a matter of urgency commission or recommission (in some cases) a Ripple Control System in all major cities to switch of geysers during peak times.

3. ZESCO uses under-frequency load shedding to disconnect large loads, in case of a system disturbance on the Southern Africa Power Pool (SAPP) interconnected system. ZESCO may

consider using the above scheme to supplement the current scheduled Load shedding scheme.

4. ZRA should institute Hydrological studies on the Zambezi River Basin in order to establish long term rainfall pattern and establish competing water needs and how they will affect power generation.

5. Evaluate previous Hydrological Studies to determine their adequacy to long lasting solutions to this current problem.

LONG TERM MEASURES (3 YEARS ONWARDS)

a. In the Long term, all current studies for generation and transmission projects must be accelerated to ensure there is a basket of well-planned projects for development e.g. Batoka Gorge Hydroelectric project, Kafubu River Hydropower project, Muchinga Hydropower project, Luchenene and Mutinondo Power projects, the Luapula River projects etc.

b. Generation Projects that are committed and are in pre-construction phases must be supported and accelerated e.g. Kafue Gorge Lower Project, Kalungwishi Hydroelectric Project, Kabompo Gorge Project, Batoka Gorge Project.

c. There is need to review the Energy Policy to address any gaps that may be identified with respect to managing emergencies or crises of a similar nature in the energy sector.

1 Introduction

In the recent past ZESCO, the national electricity utility has heightened load shedding (electricity rationing) throughout the country. The reason for this action has been attributed to insufficient water in the reservoirs at Kariba and itezhitezhi due to "below average" rainfall experienced during the 2014/15 rainy season. The load shedding averages 6-10 hours per day and affects industries, commercial undertakings, offices and domestic customers alike. This has led to a public outcry and anger against the national utility.

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1. Investigate the load shedding
2. Recommend immediate measures to reduce load shedding and
3. Recommend long term measures to avoid or minimize load shedding in future under similar circumstances.

The team set out to work and had their first meeting on 14th July 2015. Subsequent meetings took place on 4th, 7th and 28th August, 2015. Further meetings took place on 15th and 18th September, 2015. The team travelled to Siavonga for an on-the-spot check of the reservoirs on the 13th and Itezhitezhi from 20th-21st August, 2015.

On 3rd September, the team met with the Director of Generation and the Generation Support Services Manager at ZESCO. They outlined how the operations have been impacted by low inflows into the Itezhi-tezhi and Kariba reservoirs as well as the challenges that have been experienced in an effort to ensure sustainable operations into the next rainy season. Key among the challenges is that load shedding has not yielded the desired results as consumers have simply shifted the load to the time that they have electricity. In addition the mining companies were initially resistant to reduce their load but had, at the time of the meeting, agreed to do so.

During the meeting the EIZ team learnt that ZESCO had put a number of measures in place to alleviate the inconvenience load shedding causes to residential customers and to also ensure that there is a minimized interruption

in the operations of commerce and industry. Some of the measures are as follows:

- Imports from the SAPP Day Ahead Market of up to 150MW depending on availability
- Imports of 100MW from Mozambique
- Rental power of 100MW from a ship docked at Beira port.
- Emergency rental power from Aggreko of 148MW

Most of these imports come at a premium tariff due to the nature of their fuel for generation. The imports would continue until such time that they are substituted with supply from the new generation to be commissioned at Maamba (300MW) and Itezhitezhi (120MW) towards the end of 2015 and during the first quarter of 2016 as well as recovery of Lake Kariba.

2 Approach and Methodology

The team came up with a list of data that would be interrogated in order to have an appreciation of how the reservoirs have been operated in the years 2011, 2012, 2013, 2014 and 2015.

With respect to ZESCO the following sets of data was requested:

- Water level readings on 30 November, 31st December, 31st January, 28 February, 31st March and 30 April at itezhitezhi and Kafue Gorge reservoirs, as well as Kafue Gorge dam, Kasaka and Kafue Hook Bridges for 2015, 2014, 2013, 2012 and 2011.
- Operating rule (latest) curve at ITT
- Firm Power and Energy generated during the same years as above at Kafue Gorge Power Station.
- Firm Energy and Energy generated during the same years as above at Kariba North Bank Power Station
- Firm energy and Energy generated during the same years as above at Kariba North Bank Extension Power Station
- Did Kafue Gorge Dam Spill in each of the given years? If yes, provide duration of spill and volume of spill
- Most recent load forecast for the ZESCO system

With respect to the Zambezi River Authority, the following information was requested:

- Water level readings at Kariba Dam on 31st May, 30 June, 31st July, 31st August, 30 Sept and December 31st in the years 2015, 2014, 2013, 2012 and 2011
- Water level readings at the Victoria Fall on the dates above.
- Firm Generation at the Kariba Complex
- Latest Operating rule curve at Kariba Dam
- Allocated Volume to ZESCO for 2015, 2014, 2013, 2012, 2011.
- Was there spilling in the above noted years at Kariba? If yes give duration and volume of spill.
- Number upstream of Kariba Dam of stream flow monitoring stations.

A further request was given to the Department of Meteorology to provide the departments' interpretation of the 2014/15 rainy season.

Site visits were conducted on 13th and 20th August to Itezhitezhi and Siavonga respectively. This was in order to have an onsite verification of some of the information received.

3 OBSERVATIONS

From the information provided by ZESCO the following observations were made regarding the 2011-2015 period:

3.1 KAFUE RIVER SYSTEM

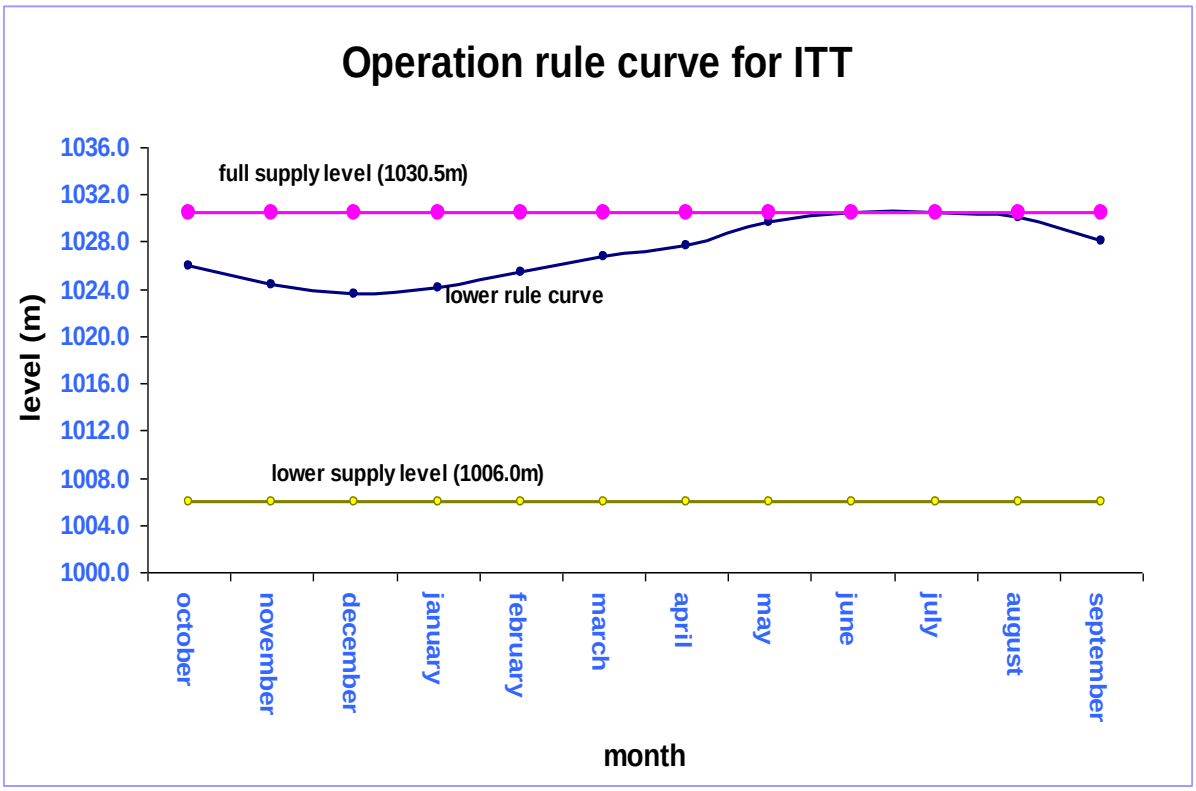

Figure 1: Operation Rule Curve for ITT reservoir

- The utilization of the Kafue water system at Itezhitezhi Dam and Kafue Gorge Dam seemed fairly normal for the period 2011-2015 as the reduction in inflows was not significant.
- Although the Itezhitezhi reservoir was not filled to maximum, it was always within 1m of the maximum retention level of 1030.5 m.a.s.l., except for 2014/15 when it fell to 2.77 m below maximum on April 30th, 2015.
- In 2013/14 the reservoir actually filled to 1030.44 m.a.s.l. which is almost the maximum retention level
- Operations at the Kafue Gorge reservoir appear to be normal for the period 2011-2015. Generation has been limited to 540 MW.

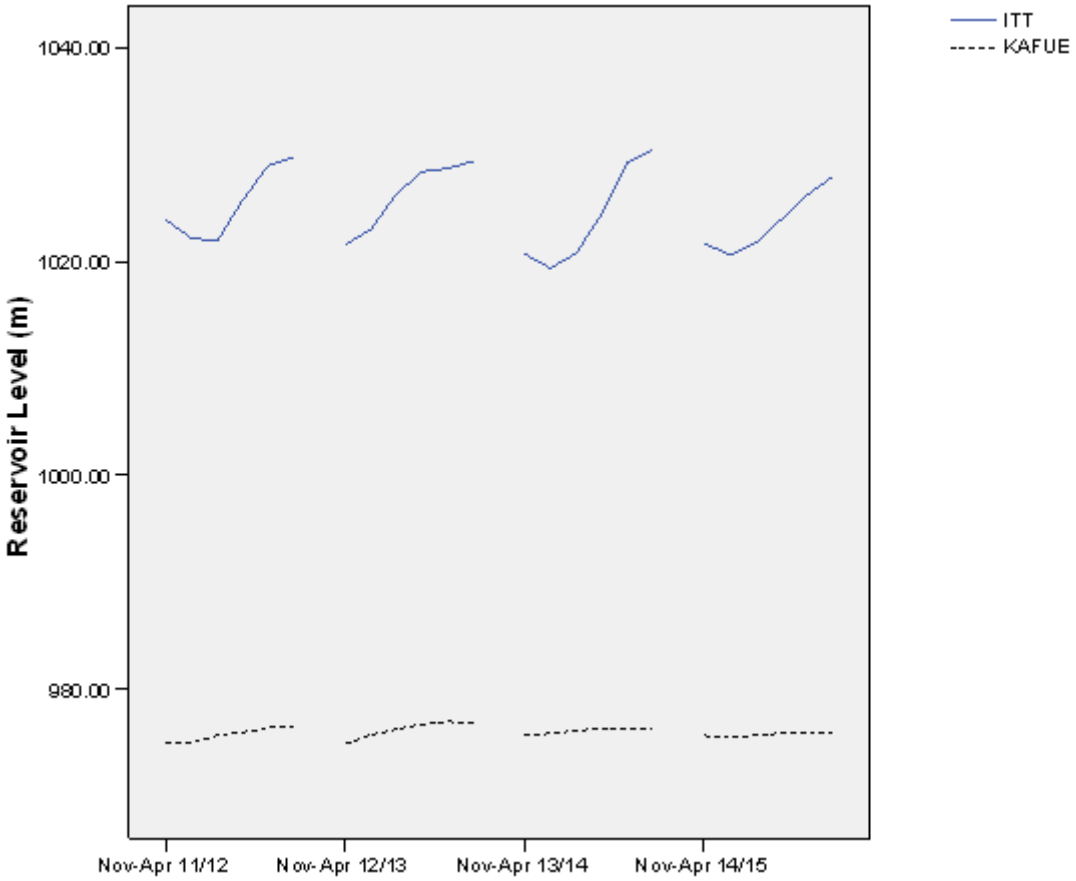

Figure 2: Reservoir Levels at Ithezitezhi & Kafue George Dams

From the information provided by Zambezi River Authority the following observations were made regarding the period 2011-2015

3.2 ZAMBEZI RIVER SYSTEM

- For the years 2011 and 2012 ZESCO did not use all the allocated water. ZESCO used 74% of its allocation in 2011 and 79% in 2012. This is attributed to the rehabilitation works that were on-going at the Power Station. In 2011 19.98 billion cubic meters was spilled for 87 days (almost one year of generation). In 2012 only 0.57 billion cu.m was spilled over 13 days.
- In 2013 and 2014 ZESCO exceeded its allocation by 5% and 22% respectively. In 2013, 1.62 billion cu.m was spilled over 18 days whereas there was no spilling in 2014.
- There has been no spilling during 2015.

Other observations for the 2011 to 2015 period at the Lake Kariba Complex are as follows:

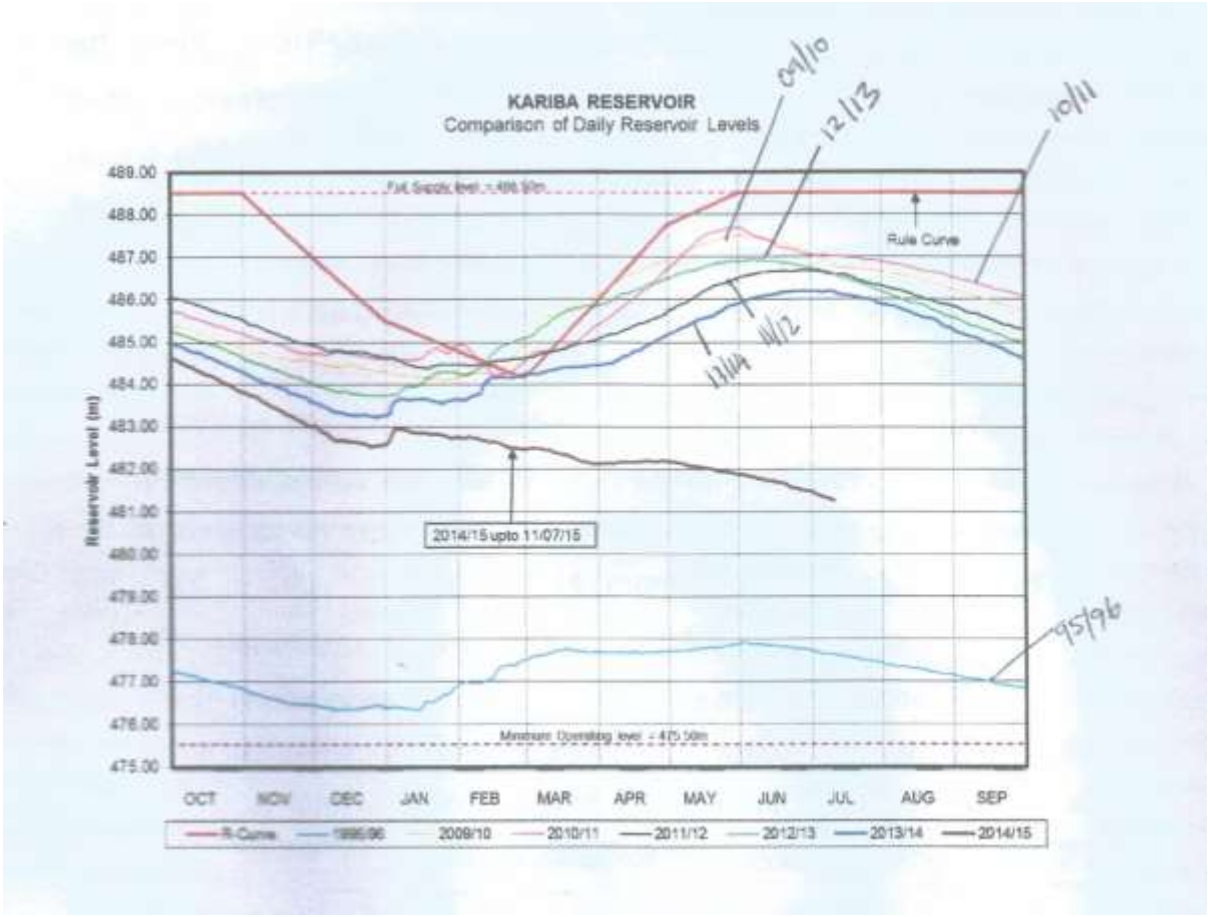

Figure 3: Kariba Reservoir Comparison of Daily Reservoir Levels

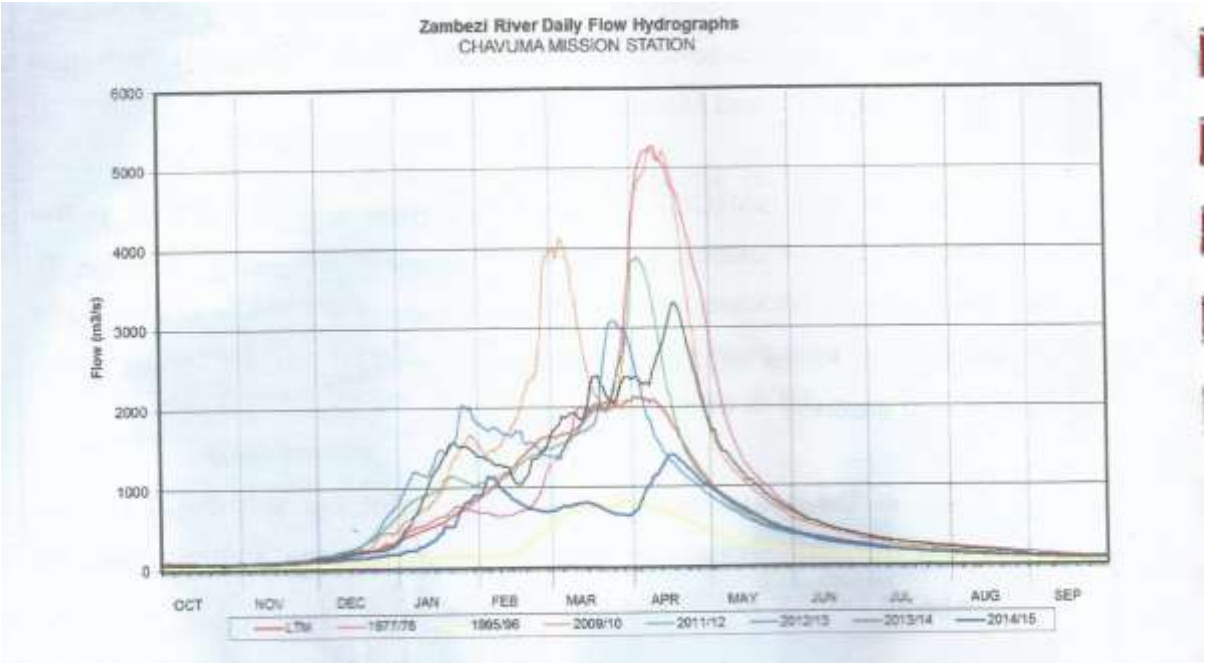

Figure 4: Zambezi River Daily Flow Hydrographs (Chavuma Mission Station)

- The reservoir has not reached its maximum retention level of 488.5 m.a.s.l. in the past 5 years.
- In October 2014, the Kariba reservoir level was at its lowest for the period under consideration at 484.6 m.a.s.l.
- The lake level has been below the expected Rule Curve for the entire period 2011-2015 except for short periods between end of January and end of March when it approached prescribed lower limit levels.
- A Rule Curve shows the minimum water level requirement in the reservoir at a specific time to meet the particular needs for which the reservoir is designed. It is important to note that rule curve shall be followed except during periods of extreme flood/drought and when public interest so requires. However for the Kariba complex the upper rule curve is a function of dam safety as opposed to power generation. Hence under normal operations the maximum retention level at Kariba should not be exceeded.
- Firm power for Kariba (North and South Banks combined) is 640 MW at 99% reliability. The Current operations at the Kariba complex are way above this threshold hence have greatly reduced the reliability of the reservoir.
- The spill of 19.98 billion cubic meters in 2011(2010/11, rainy season) does not look justifiable as the reservoir storage level was way below the rule curve. An explanation was that there was a restriction on spillway gates as only one spillway gate was in good operating condition at the time hence the reservoir needed to be drawn down in anticipation of higher floods.

3.3 Information from the Department of Meteorology

Information obtained from the Department of Meteorology shows that the upper reaches of the Zambezi River such as Mwinilunga and Zambezi received below normal rainfall whereas the middle reaches such as Mongu, Sesheke and Livingstone received normal rainfall. For the Department of Meteorology, normal rainfall is 75-125% of expected figures whereas anything less than 75% is considered to be below normal.

Table 1: Rainfall Performance as at 10th April, 2015

RAINFALL PERFORMANCE AS AT 10TH APRIL, 2015				
STATION	**seasonal total**	**normal**	**departure**	
mwinilunga	972	1326	-27%	Below
mansa	1006	1064	-5%	Normal
kasama	1026	1233	-17%	Normal
zambezi	1125	1664	-32%	Below
kasempa	1048	1149	-9%	Normal
ndola	1217	1162	5%	Normal
chipata	827	992	-17%	Normal
kawambwa	1419	1293	10%	Normal
misamfu	1020	1233	-17%	Normal
isoka	827	1059	-22%	Normal
msekera	879	977	-10%	Normal
lundazi	682	861	-21%	Normal
lusaka city	720	818	-12%	Normal
Mongu	814	919	-11%	Normal
Solwezi	1123.9	1330	-15%	Normal
Livingstone	635.5	761	-16%	Normal
Kaoma	1080	928	16%	Normal
Sesheke	574	699	-18%	Normal
Chipepo	649.3	760	-15%	Normal

Note: Normal 75% to 125%
Below Normal below 75%
Data provided by Dept. of Meteorology

4 2014/15 Operations at the Kariba Complex

From the information received it is clear that Lake Kariba started the year 2014/15 on a lower reservoir level than the previous 5 years with approximately 40 billion cubic meters in storage at 30th September 2014. The allocation for 2015 was 45 billion cubic meters. This means all the available water was allocated for power generation. Further the inflows during the subsequent months were lower than the outflows from the power plant leading to a net drawdown of the reservoir.

ZRA became aware of the low inflows as early as December 2014 and started reviewing their simulations for a probable below normal rainfall. In March

2014, ZRA first informed the utilities of the impending crisis but did not reduce water allocation for power generation. Later, during the same month, when it became clear that the inflows were subdued, ZRA revised the water allocation downwards to a total of 33 billion cubic meters and informed the two utilities to restrict their maximum generation to 500 MW each, down from a possible 700MW each according to the initial water allocation.

The ZRA report (July 2015) shows that despite the restriction, the utilities continued to generate way above the revised threshold of 500MW leading to a net draw down of the reservoir.

At the time the EIZ team visited the Kariba North Bank Power Station on 20th July 2015, generation was at 760MW.

The ZRA report concludes that if generation is not reduced in line with their recommendations, the storage reserved for power generation will be depleted by November 2015 leading to a complete shutdown of the power plants. Although the designed live storage for power generation at Kariba is 65 billion cubic meters the reservoir has not been filled to capacity in the past 4 years and 40-42 billion cubic meters has been allocated for power generation in each year.

It is interesting to note that a 2010 report sponsored by ESKOM titled Impact of Climate Change on Hydro-Electric Generation in the Zambezi River Basin puts the 30 year (1970-2000) historical average storage in Kariba at 33.244 billion cubic meters. This figure is way below the designed storage of 65 billion cubic meters. It is important that Kariba being a multi-year storage reservoir effort is made to keep the reservoir as high as possible during each year.

The Kariba dam was designed as a multi-year reservoir this means one average rainy season is not sufficient to fill it up. Further if operated at the designed firm generation; there is sufficient water for 3 rainy seasons. This means a single drought event should not drastically impact negatively operations of the power stations particularly when the drought is preceded by an average rainy season. There is therefore need to revise the way the reservoir is currently operated.

Overall, the effects of the increasing load from all sectors of economic activity have had a toll on the hydropower resource. Whilst Zambia's installed capacity is sufficient to meet the needs of the economy, the "fuel" (water) is currently a big constraint as it is provided by nature.

4.1 Efficiency of Turbines

The turbines at the power plant are quiet efficient in the use of the water resource. The new units have a guaranteed efficiency of 93% at an operating head of 89m. The maximum efficiency is 95.99%. The old units have a guaranteed efficiency of 92% at an operating head of 88m. The guaranteed efficiency is 94.18%. Apart for reasons of scheduled maintenance and other repair works the generating units' availability is good.

5 DEMAND FORECAST BY CUSTOMER CATEGORY (ZESCO)

5.1 Residential and Commercial Customers Energy Demand Forecast

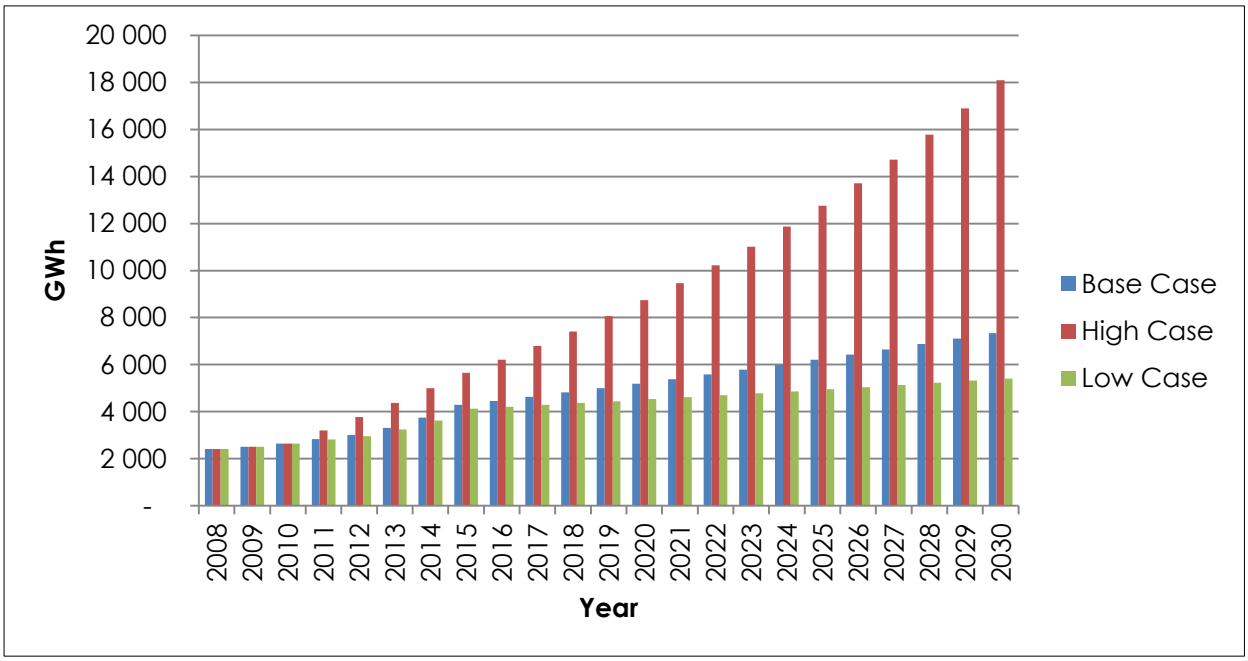

Figure 5: Residential & Commercial Customers - Energy Demand Forecast (ZESCO)

5.2 Industrial Customers Demand Forecast (ZESCO)

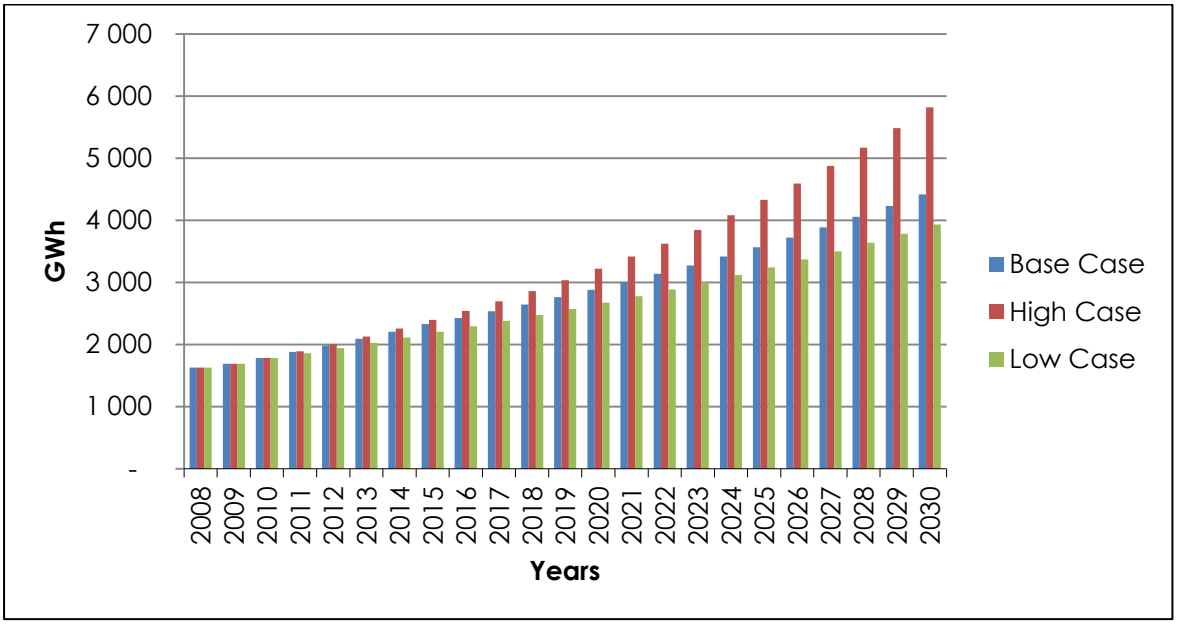

Figure 6: Industrial Customers Demand Forecast (ZESCO)

5.3 Mining Customers Demand Forecast (ZESCO)

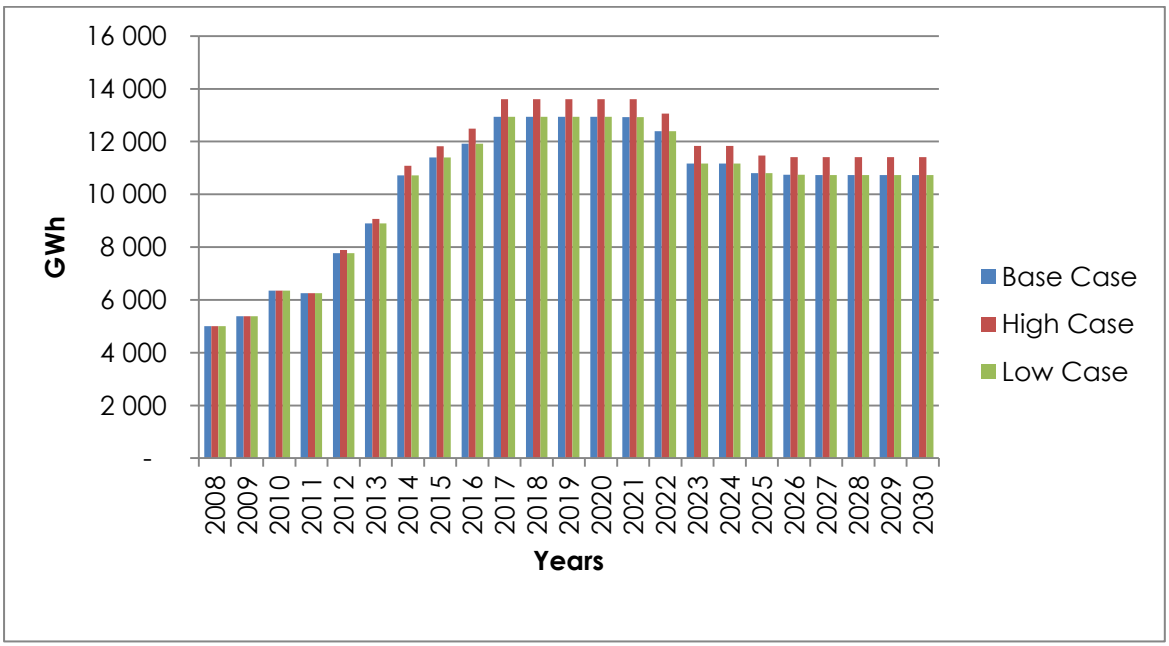

Figure 7: Mining Customers Demand Forecast (ZESCO)

5.4 National Total Demand Forecast

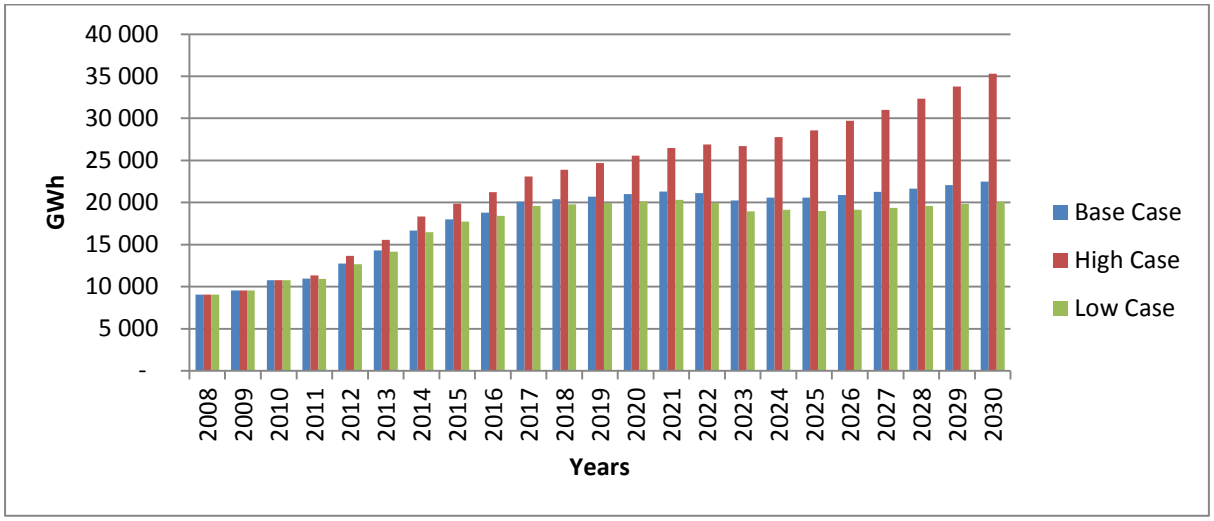

Figure 8: National Total Demand Forecast

6 Impacts of Climate Change

The Intergovernmental Panel on Climate Change (IPCC) identified the Zambezi River as one of the two rivers in Africa that are sensitive to climate change and urges that effects of climate change should be taken into account in the planning and operation of hydropower project. The Zambezi River is particularly sensitive to global warming.

A number of studies have been done to predict the behavior of the reservoirs under climate change but so far the outcomes are yet to be considered in the operation of the hydropower power plants on the Zambezi River.

It could well be that the low inflows experienced during the 2014/15 season are as a result of climate change.

7 Conclusions

From the information received the following conclusions can be made:

1. The issue of low inflows was identified early however there was a delay in implementing measures to forestall the “business as usual” operations.
2. According to data from the Department of Meteorology the upper reaches of the Zambezi River (upstream of Katima Mulilo)

received below normal rainfall. The middle reaches had normal rainfall. However the flows though normal were skewed towards the negative side.

3. The release of 19.98 billion cubic meters (an equivalent of almost one year of generation for either of the power plants) over an 87 day period in 2011, though attributed to dam safety measures, due to restrictions in the availability of spillway gates, at that time, may not have been prudent as there was no imminent danger paused by the inflows. This release led to Kariba operating with bare minimum of water required for power generation.
4. The low reservoir levels for the 2014/15 season cannot be attributed to the poor inflows alone as the daily reservoir curves show that during the 2013/14 hydrologic season the reservoir was 80% filled during the month of July. There was an element of over generation at the Kariba complex.
5. ZESCO exceeded its water allocation by 22% during 2014.This coupled with low inflows, is a contributor to low water levels being experienced.
6. The increase in economic activities over the years has led to an increase in demand for energy and has put stress on the water resource.
7. Despite the end of March 2015 directive from ZRA to the two utilities to reduce generation, this was not immediately implemented until, in ZESCO's case, August 2015. This led to further drawdown of the reservoir threatening total shut down of the power plant.

8. RECOMMENDATIONS

8.1 Measures with impacts in the short term (0-1 Year)

In order to minimize the threat to depleting the water resource, efforts should be directed at Demand side Management.

a. Customers must be encouraged to switch off non-essential loads such as geysers, hot elements, swimming pool pumps etc.

b. Large industrial plants like the Mines operating Change Houses should switch to Solar Hybrid Geysers.
c. Customers must be encouraged to use energy efficient equipment such as energy efficient lamps. ZESCO should continue with the exercise of distributing free/exchanging with energy efficient lamps.
d. Customers in low density and medium residential areas should be encouraged to switch to LPG or other suitable gas for cooking.
e. Government should issue a statutory instrument directing that all new housing estates use hybrid solar water geysers for heating water and that existing households should be given a fixed period to migrate to hybrid solar geysers.
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h. ZESCO should conduct energy audits in Industry with the view to encourage energy efficiency e.g. improving power factor.
i. ZESCO uses under-frequency load shedding to disconnect large loads, in case of a system disturbance on the Southern Africa Power Pool (SAPP) interconnected system. ZESCO may consider using the above scheme to supplement the current scheduled Load shedding scheme.
j. Power Projects under construction must be supported and expedited e.g. Maamba Coal power plant and Itezhitezhi Hydroelectric Power Station.

8.2 MEDIUM TERM MEASURES (1-3 YEARS)

a. In the medium term, On-Grid and Off-Grid renewable energy technologies should be exploited as solutions for distributed generation. In particular small hydro, Solar, Biomass, Bio-gas etc. must be promoted.

b. Solar energy has rapidly emerged as a clear viable option in recent years. Zambia and Southern Africa in general have good solar resource. Solar energy is now cost competitive with traditional sources of power like coal and hydro. It is a clean source of energy. It can be deployed much faster (1-2 years for utility scale power plants) compared to 2-5 years for coal and hydro power plants. South Africa already has several utility scale solar power plants and several other African countries are following suit. Solar also works with hydro very well as a hybrid system. In view of its advantages, Zambia should fast track some utility scale solar power plants.

c. ZESCO should as a matter of urgency commission or recommission (in some cases) a Ripple Control System in all major cities to switch of geysers during peak times.

d. ZRA should institute Hydrological studies on the Zambezi River Basin in order to establish long term rainfall pattern and establish competing water needs and how they will affect power generation.

e. Evaluate previous Hydrological Studies to determine their adequacy to long lasting solutions to this current problem.

8.3 LONG TERM MEASURES (3 YEARS ONWARDS)

a. In the Long term, all current studies for generation and transmission projects must be accelerated to ensure there is a basket of well-planned projects for development e.g. Batoka Gorge Hydroelectric project, Kafubu River Hydropower project, Muchinga Hydropower project, Luchenene and Mutinondo Power projects, the Luapula River projects etc.

b. Generation Projects that are committed and are in pre-construction phases must be supported and accelerated e.g. Kafue Gorge Lower Project, Kalungwishi Hydroelectric Project, Kabompo Gorge Project, Batoka Gorge Project.

c. There is need to review the Energy Policy to address any gaps that may be identified with respect to managing emergencies or crises of a similar nature in the energy sector.

9. Caution

El Nino Southern Oscillation (ENSO) is a phenomenon in which the sea surface temperature in the Eastern Pacific goes up every 2-7 years. The occurrence of ENSO is associated with wide scale (global) changes in rainfall and other climatic events. For Southern Africa, ENSO is generally associated with dry and warm spells. Currently there is an ENSO event building up in the Pacific.. According to the latest international forecasts by National Oceanic and Atmospheric Administration (NOAA), "There is greater than 90% chance that El Nino will continue through Northern Hemisphere winter 2015-16 and around an 85% chance it will last into early spring 2016". This means that Zambia may face a shortage of rainfall in the next rainy season. ZESCO needs to be aware of it and consider this factor in their future planning.

NOTE

The issue of increasing tariffs to cost reflectivity as an immediate measure to curb demand and reduce wasteful practices was discussed but not all members agreed to have it included in this report as a recommendation. Those in favor view it as a possible deterrent to misuse and inefficient use of electricity whilst those against view electricity as a major driver for development particularly when access to electricity is still very low (25% for Zambia).

Technical Experts Team

The under-listed officials composed the team of experts;

Eng. Israel Phiri

Eng. John Muleya

Eng. Clement Mukosa

Eng. Alec Malichi and

Prof. Prem Jain.