FINAL

New & Renewable Energy Development Corporation of Andhra Pradesh Ltd.,

(A State Govt. Company- ISO 9001 :2015 Certified)

(Formerly Non-Conventional Energy Development Corporation of Andhra Pradesh Ltd.,)

Project Location: Gandikota

Taluk: Gandikota

District: Kadapa

Latitude: 14.81

Longitude: 78.25

TECHNO-COMMERCIAL FEASIBILITY REPORT

LOCATION: GANDIKOTA

PROJECT REPORT SERIAL NO:
P1/23-ON-1

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MAY, 2020

LIST OF THE PROJECT SITES (23 Nos.)

I. ON RIVER PROJECT SITES:

Project Code	Location	Taluk	District	Latitude	Longitude
P1/23-ON-1	**Gandikota**	**Gandikota**	**Kadapa**	**14.807928**	**78.251503**
P2/23-ON-2	Owk Reservoir	Jammalmadugu	Kurnool	15.185044	78.085161
P3/23-ON-3	Somasila	Atmakur	Nellore	14.487423	79.303349
P4/23-ON-4	Chitravathi	Tadimarri	Anantapur	14.561015	77.958636

II. OFF RIVER PROJECT SITES:

Project Code	Location	Taluk	District	Latitude	Longitude
P5/23-OFF-1	Baddumasingi	Palakonda	Srikakulam	18.7069	83.7264
P6/23-OFF-2	Lambasingi	Chintapalli	Vishakapatnam	17.8564	82.4658
P7/23-OFF-3	Yerravaram	Atchutapuram	Vishakapatnam	17.7661	82.4564
P8/23-OFF-4	Gathapanuku	Paderu	Vishakapatnam	17.9681	82.7611
P9/23-OFF-5	Kadapayapalle	Siddhavattam	Kadapa	14.5997	78.9439
P10/23-OFF-6	Vongimalla	Veeraballi	Kadapa	14.2431	78.8783
P11/23-OFF-7	Chintarajupalle	Vontimiita	Kadapa	14.315	78.9233
P12/23-OFF-8	Duggeru	Makkuva	Vizianagaram	18.7506	83.1122
P13/23-OFF-9	Peda Rabha	Ananthagiri	Vishakapatnam	18.2314	83.0406
P14/23-OFF-10	Chittamvalasa	Ananthagiri	Vishakapatnam	18.2294	82.9083
P15/23-OFF-11	Pedakota	Ananthagiri	Vishakapatnam	18.1019	82.8756
P16/23-OFF-12	Sirijam	Cheedikada	Vishakapatnam	18.0647	82.8264
P17/23-OFF-13	Varukaru	Paderu	Vishakapatnam	18.0539	82.6958
P18/23-OFF-14	Tatiparthi	Madugula	Vishakapatnam	17.9417	82.6589
P19/23-OFF-15	Z Kothapatnam	Ravikantham	Vishakapatnam	17.8861	82.5869
P20/23-OFF-16	Chimalabayalu	Chintapalle	Vishakapatnam	18.0575	82.4725
P21/23-OFF-17	Palamamidi	G Madugula	Vishakapatnam	17.9647	82.5581
P22/23-OFF-18	Thotaluru	Koyyuru	Vishakapatnam	17.7992	82.3172
P23/23-OFF-19	Krishnadevipeta	Golukonda	Vishakapatnam	17.7567	82.2781

Techno-commercial Feasibility Reports for Pumped Storage Project
At
Gandikota site
in Kadapa district of Andhra Pradesh

Prepared for	New & Renewable Energy Development Corporation of Andhra Pradesh Ltd.,
Represented by	VC & Managing Director, NREDCAP

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CHAPTER – 1

1. EXECUTIVE SUMMARY

1.1 Introduction

India is a fast-growing economy experiencing rapid industrialization, irrigation development, urbanization, improved village infrastructure etc. The demand for power which is one of the basic inputs for the economic growth of a country is therefore, on the rise in India. The chief sources of energy which are utilized for generation of electricity are: Fuel in all forms i.e. solid, liquid and gaseous, water energy and nuclear energy. The other sources of energy are sun (solar photo-voltaic etc.), wind and tides.

Hydro-power is a renewable, economical, non-polluting and environmentally benign source of energy. Hydropower stations have inherent ability for instantaneous starting and stopping, to help in improving reliability of power system and to meet the peak demand. Hydroelectric projects have long useful life and help in conserving scarce fossil fuels.

Pumped Storage Project is a type of hydroelectric generation plant that stores energy in the form of water, pumped from a lower elevation reservoir to upper elevation reservoir during off-peak period and generates electricity during peak period. This is currently one of the most effective means of storing large amount of electric energy. It helps in grid stability, reliable supply and providing quality power (in terms of voltage and frequency). In any typical PSP the water from Upper Reservoir passes through the waterways to the turbines installed at the power house to generate power during peak hours. The tail water is diverted through the tunnel to store water in the lower reservoir. The excess water from upper/lower reservoir (if any) gets discharged through spill way. During off peak hours the excess power from thermal stations and other sources will be fed back to pump the water from Lower Reservoir to Upper Reservoir through power house where generators and turbines then acts as motors and pumps respectively. The same cycle of operation gets repeated during peak and lean period.

The peak electricity demand of A.P. has been on increase at a fast pace and for the year 2021-22 it has been estimated as 11843 MW. Though hydro power provides an environment friendly peaking power, only 1673.6 MW of hydro-power capacity has been installed in A.P so far. This is where NREDCAP is playing an effective role. By the end of Dec 2019, Renewable energy power projects with total capacity of 8142.768 MW have been commissioned in A.P. Majority of which are solar and wind schemes. The development of PSP, particularly in the areas concentrated with wind and solar generations would significantly improve the

grid reliability and would act as the best partner for the reviewable energy integration. NREDCAP has identified 23 locations in A.P. for pre-liminary examinations for development of power through PSP and has awarded the work of preliminary of techno-commercial feasibility Reports to WAPCOS vide order no. NREDCA/WE/PSP/2019 Dt. 13.12.2019.

1.2 Project Background

The proposed Gandikota Pumped Storage project envisages utilization of available head between proposed upper dam and existing Gandikota reservoir as lower pond. An Underground Power House (UGPH) will be located in between two reservoirs. Both the reservoirs will be interconnected through water conductor system and the generator and turbines installed at the power house.

Preliminary studies will help for preparation of prefeasibility report of Gandikota Pumped Storage schemes in Andhra Pradesh, which aims to strengthen the power position and flexibility to control the frequency of the power grid and power requirement of the state and utilisation of generated power during peak hours of power demand and utilisation of excess power during lean hours for pumping of water to upper reservoir.

The topography indicates that the Upper and Lower Reservoirs have effective storage capacity sufficient for maximum hours of generation daily at full rated output, it is possible to operate the project on daily basis only. An Inter-disciplinary team of expert engineers consisting of concept layout designers, Hydrology expert and other civil, mechanical and electrical engineers and geologist visited project site from the period of 3rd to 5th Jan 2020. A site visit report along with the photographs are shown at **Appendix-I**.

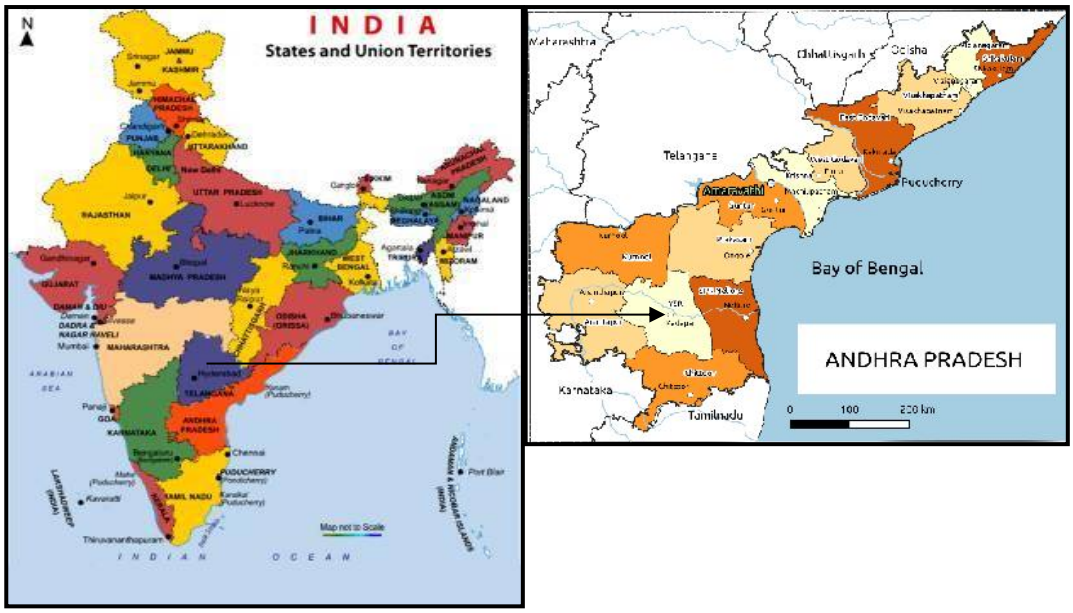


Figure –1.1: Location Map

Source: - Google Earth

1.3 Project Location

The proposed Gandikota Pumped Storage Project is located in Kondapuram village of Kadapa district of Andhra Pradesh, India **(Figure 1: Location Map)**. The project falls in the Lat. N 14° 49' 47" & N 14° 48' 28" and Long. E 78° 13' 53" & E 78° 15' 5". It is located 93 KM towards west from District headquarters Kadapa. The Upper reservoir at present is not accessible but the Lower is accessible to nearest road network which is at about 5 km from NH-67. Upper dam falls in govt. land and there is no habitation. Lower dam is utilized for Irrigation, Drinking water and fisheries.

1.4 Access to the Project

The Project is located in Kondapuram village in Kadapa district in the state of Andhra Pradesh in India. The nearest rail head is Mangapattinum which is about 15 km from Yeddula Eswar Reddy (Gandikota) Reservoir and with loading & unloading facility. The nearest airport is Kadapa which is 100 km (approx.) from project site. The nearest se5a port is Krishnapatnam Port & is about 230 km from the project site.

1.5 Scope of Work

The project is envisaged to be a Pumped Storage Scheme consisting of two reservoirs: one at lower elevation and other at upper elevation, to provide the effective "head" for power generation. The water conductor system will connect the two reservoirs through an underground power house

The scope of work envisages preliminary studies for:

- Collection of available hydrological/meteorological data and assessment of water availability for the project.
- To examine the use of existing Gandikota reservoir of gross storage capacity of **26.84 TMC (759.6 MCM)** to serve as Lower reservoir which has a live storage capacity of **23.72 TMC (671.28 MCM)**
- To select the location of Upper dam to provide maximum live storage within Full Reservoir Level (FRL) and Minimum Draw down Level (MDDL).
- Selection of location of an underground power house. To finalize the tentative orientation of the powerhouse on preliminary geotechnical, engineering and hydraulic aspects.
- To select the location of an underground Transformer Cavern.
- Secondary Gas Insulated or open Switchyard to be arranged in the Cavern or open yard for the Transformers. These Transformers will be connected by bus duct galleries to machine hall.
- Preliminary geological, geotechnical and engineering appraisal of Head Race Tunnel cum pressure shaft and Tail Race Tunnel for conveyance of water.
- Power potential studies.
- Tentative estimation of cost and benefits of the project.

1.6 Topography & Climate

The proposed Project is located in village Kondapuram in Kadapa district in the state of Andhra Pradesh in India and belongs to Rayalaseema region. The area has a tropical wet and dry climate characterized by year-round high temperatures. It has a record of reaching more than 50 degree Celsius. Summers are especially uncomfortable with hot and humid climate. During this time temperatures range from a minimum of 34 °C and can rise up to a maximum of 40 °C. Humidity is around 75% during the summer months. Monsoon season brings substantial rain to the area. It gets rainfall from both the South west monsoon as well as the North East Monsoon. June to October is usually the monsoon. Winters are comparatively milder and the temperatures are lower after the onset of the monsoons. During this time the temperatures range from a maximum of 25 °C and can rise up to a maximum of 35 °C. Humidity is much lower during the winter season. The average annual rainfall of the district Kadapa is 710 mm, which ranges from nil rainfall in January to 137 mm in October.

1.7 Geology

The project area lies in the southwestern part of the Kadapa district of Andhra Pradesh. Different types of landforms like structural hills, pediment-pediplain, plateau etc. are found in and around the project area. Quartzite belonging to Gandikota Quartzite Formation, shale and tuff of Tedpatri Formation, both under Chitravati Group are present in and around the project site. The general strike of the rocks is N40°W-S40°E and dip 5°-15° towards N50°E.

The proposed project envisages construction of an artificial reservoir in the upper reaches where the water is passing through a HRT-Pressure shaft- penstock to an Underground powerhouse- TRT to the lower reservoir located at the lower reaches. Two alternate proposals of combined bund & pit upper reservoir have been studied by WAPCOS. The option-1 is located 1925.0m NNW of the existing reservoir and option-2 is located 4.3Km southeast of the existing lower reservoir. Option-1 is selected on the basis of techno-economic feasibility study. However, detailed study of all alternative options will also be done at DPR stage.

1.8 Seismicity of the Project Area

As per Seismic Zonation Map of India (IS 1893 – 1984) the district Kadapa falls in Zone II (least active seismic zone) and Zone III (moderate seismic zone). 91% of the total area and 95% of the total population of the district falls in Zone II; while 9% of the total area and 5% of the total population falls in Zone III.

The project area falls under seismic zone-II.

1.9 Installed Capacity and Power Generation

The factors that influence the installed capacity of pumped storage scheme at a site are the requirement of daily peaking hours of operation, operating head, live pondage in the reservoirs and their area capacity characteristics: Based on the study on above parameters the key details of the scheme are summarized below:

Installed Capacity (MW)	600 MW
No of units	2 nos.
Unit Size (MW)	300
Type of Turbine	Vertical reversible Francis Turbine
Head (min) (m)	253.50 m
Net Design Head (m)	269.87 m

Head (max) (m)	282.6 m
Hours of Peaking Operation	5 hrs 5 Min,
Annual Energy Generation (GWh)	1113.25 GWh
Annual Pumping Energy (GWh)	1390.65 GWh
Cycle Efficiency (%)	80.05%
Head Loss (m)	6 m
Life of Project	40 Years

1.10 Land Requirement

The total land to be acquired for the project is approximately 350 acres. Based on the site visit, most of the land required is Forest and Government (revenue) land. The clearance and acquisition of land will be as per the land guidelines. Suitable site will be selected for much disposal at FSR/DPR stage. The various components of the land required is shown in Table below:

S.No.	Appurtenance	Area (Acre)
1.	Project Component	260
2.	Roads	20
3.	Muck Disposal/ Quarry Site	50
4.	Contractor's facility	20
	Total	**350**

1.11 Power Evacuation Arrangement:

The power generated from the project at different voltages will be stepped up to HV with the help of a Transformer in relation with HV substation where the generated power will be evacuated through transmission line. The proposed Gandikota Pumped Storage Plant is of the installed capacity of 600 MW which consists of 2 unit of 300 MW each. Therefore, considering the n-1 contingency criteria, it is proposed to evacuate the power from 2 nos. D/C 400 kV transmission line which would be connected to nearest grid.

Further, the following options are proposed for evacuating the power of Gandikota Pumped Storage Project –

1. 2 nos. D/C Single Moose 400 kV Transmission Line from Gandikota Power House to 400 kV existing substation at Rayalseema 400kV Substation – Length of each line shall be approx. 27 km.
2. 2 nos. D/C Single Moose 400 kV Transmission Line from Gandikota Power House to 400 kV existing substation at Gooty – Length of each line shall be approx. 72 km..

1.12 Estimates of the Cost

The estimated project cost is ₹ **1,772.71 Crores** at December, 2019 price levels. The preliminary cost estimate of the project has been prepared as per guidelines of CEA / CWC. The Abstract Summary of the cost estimates is given below

Item	**Estimated Cost (₹ Crores) (Dec. 2019)**
Civil Works	₹ 642.85
Electro-mechanical Works	₹ 1129.86
Total	**₹ 1,772.71**

1.13 Financial Aspects

The estimated cost of the project is ₹ **1,772.71** Crores at December, 2019 price levels and will provide annual energy generation of 1113.25 Gwh. The project is proposed to be completed in a period $4^{1}/_{2}$ years. The tariff has been worked out considering a debt-equity ratio of 70:30, and interest rate of 10% on the loan component for the financial analysis of the project. Based upon the parameters given above, the first year and levelized tariff is indicated below. The off-peak energy rate has been considered as **(₹3/kWh)**

Sl. No.	**Off Peak Energy Rate (₹/kWh)**	**First Tariff (₹/kWh)**	**Levelized Tariff (₹/kWh)**	**conversion cost of the project (excluding pumping cost) (₹/kWh)**
1	3	8.21	7.72	3.67

However, Levelized tariff for the project life 50 years & 60 years comes out as ₹/kWh 7.74 & ₹/kWh 7.76 respectively

1.14 Conclusion & Recommendation

Present report is prepared based on the limited available data which was collected and subsequently analysis and studies were carried out by WAPCOS. Gandikota Pumped Storage Project involves minimum and simple civil works and could be completed in 4 and ½ years. The project would afford an annual design energy generation of 1113.25 GWh per year. The cost per MW installed works out as approx. ₹ 2.95 crore / MW.

It may be pertinent to mention here that it is likely that the availability of more off peak power will be available in the grid due to projected injection of solar, wind etc. In such scenario more cycle operation in a day is possible, which will further reduce the tariff and enhance the viability of the project.

This report indicates that Gandikota PSP scheme has merits from technical and financial aspects. In view of above Gandikota Pumped Storage Project is recommended for taking up for FSR / DPR.

1.15 Salient Features

1. LOCATION	
Country State District	India Andhra Pradesh Kadapa
River	Pennar River
Upper Reservoir	Lat. N 14° 49' 47.28" & Long. E 78° 13' 53.23"
Gandikota Reservoir (Lower Reservoir)	Lat. N 14° 48' 28.54" and Long. E 78° 15' 5.41"
Access to the Project	
Road	5 Km from National Highway 67
Airport	Kadapa: 100 km;
Railhead (with unloading facilities)	Mangapattinum : 15 km
Port	Krishnapatnam : 230 km
2. PROJECT	
Type	Pumped Storage Project
Installed Capacity	600 MW
Peak Operating duration	5 Hours 5 min,
Average Annual Rainfall	710 mm
3.0 CIVIL STRUCTURE	
3.1 UPPER RESERVOIR (New) (Bund Type)	

Height of Bund	23 m
Length of Bund	5041m
FRL	EL. 490 m
MDDL	EL. 470 m
Available Live storage	0.159 TMC (4.67 MCM)
3.2 LOWER RESERVOIR (Existing)	
FRL	EL. 212.00 m
MDDL	EL. 202.9 m
Live storage	23.72 TMC (671.28 MCM)
Dead Storage	3.12 TMC (88.33 MCM)
3.3 Headrace Tunnel (Concrete Lined)	
Diameter	8.43 m
Length	353.00 m
No. of Tunnel	1
3.4 Pressure Shaft (Steel Lined)	
D x L x line After Bifurcation	6.76m x 379m x 1 lines 4.80m x 70m x 2 lines
3.5 Tailrace Tunnel (Concrete Lined)	
Diameter	8.43 m
Length	705 m
No. of Tunnel	1
3.6 Powerhouse	
Type Size	Underground, 119 m x 22 m x 49 m
3.7 Transformer Room including Secondary GIS	
Type L x W x H	Underground 100 m x 18m x 22.5 m
3.8 Main Access Tunnel (MAT)	
Type W X H	D-shape 8.00 m x8.00 m
4.0 Electromechanical Equipment	
4.1 Pump Turbine	
Type	Vertical reversible Francis Turbine
Number of units	2 (Two)

Max. Head as Turbine	282.60 m
Rated Turbine Head	269.87 m
Min. Head as Turbine	253.50 m
Turbine Output at Rated Head	304.57 MW
Turbine Output at 10% overhead operation	330.00 MW
Max. Head as Pump	291.60 m
Rated Pump Head	278.87 m
Min. Head as Pump	262.50 m
Max. discharge of Turbine at rated Turbine head	129.26 Cumec
Specific speed at net pump head	33m- m3/sec
Rated Speed	250 rpm
4.2 Generator-Motor	
Type	3 phase AC Synchronous Generator – Motor, Semi Umbrella Type
Number of units	2
Rated Capacity	300 MW
Rated terminal voltage between phases	18 Kv ± 10%
Rated Frequency	50 cycles per second
Rated Speed	250 rpm
Over Load Capacity (10%)	330 MW
4.3 Transmission Line	
Type	Double Circuit Moose Conductor
Capacity Voltage Level	400 kV
Length	• 400kV Substation – Length of each line shall be approx. 27 km. • 400 kV existing substation at Gooty – Length of each line shall be approx. 72 km..
5.0 Project Cost	
Item	**Estimated Cost (₹. crores)**

Civil Works		₹642.85		
Electro-mechanical Works		₹ 1129.86		
IDC		₹ 295.20		
Total		**₹ 1772.71**		
6.0 Project Benefit's				
Sr.No.	**Off Peak Energy Rate (₹/kWh)**	**First Tariff (₹/kWh)**	**Levelized Tariff (₹/kWh)**	**conversion cost of the project (excluding pumping cost) (₹/kWh)**
1	**3**	**8.21**	**7.72**	**3.67**

CHAPTER-2: ECONOMIC SCENE OF ANDHRA PRADESH

CHAPTER- 2

2. ECONOMIC SCENE OF ANDHRA PRADESH

2.1 Introduction

Andhra Pradesh has been one of the progressive States of India. It is located in the Southern peninsula of India. The state is bound by Chhattisgarh on the north, Odisha on the northeast, Telangana and Karnataka on the west, Tamil Nadu on the south, and the Bay of Bengal on the east. The erstwhile state of Andhra Pradesh has been bifurcated into two states, Telangana and residuary Andhra Pradesh (Seemandhra), by the Andhra Pradesh Reorganisation Act, 2014 also known as the Telangana Act. The state of Andhra Pradesh is made up of the two major regions of Rayalaseema, in the inland southwestern part of the state, and Coastal Andhra to the east and northeast, bordering the Bay of Bengal. The state comprises thirteen districts in total, nine of which are located in Coastal Andhra and four in Rayalaseema.

The Andhra Pradesh has been blessed with rich natural resources by the nature. Amongst all States, Andhra Pradesh tops in various socio-economic indicators. The state has well-developed social, physical and industrial infrastructure and virtual connectivity. It also has good power, airport, IT and port infrastructure. The economy of Andhra Pradesh is one of the fastest growing economies in India, with growth outstripping that of the wider Indian economy in the past few years.

The GSDP (Gross State Domestic Product) of Andhra Pradesh at constant (2011-12) Prices for the year 2018-19 (Advance Estimates) indicate a growth of 11.61% as against for 2015-16 (First Revised Estimates). Per Capita Income at current prices increased to ₹122,376 from ₹108,163 in 2015-16 registering a growth of 13.14%. The economy is primarily dependent on agriculture, which directly and indirectly employs 62% of the population.

With a geographical area of 1, 62,970 Sq Km, Andhra Pradesh ranks as the 8th largest State in the country. Situated in a tropical region, the state has the 2nd longest coastline in the country with a length of 974 Km. As per the forest records, the state ranks 9th in India having forest cover area of 37707 Sq. Kms which amounts to 23.54% of the total geographical area. In terms of population, Andhra Pradesh is the tenth largest state in the Country accounting for 4.10% of the total population of the country, as per 2011 Census. The density of population for Andhra Pradesh is 304 persons per square kilometer, as against 382 persons per square kilometer at all India level in 2011. The literacy rate of the earstwhile state is 67.7 percent in

2011 as compared to 62.07 percent in 2001. The literacy rate of the State is lower than the all India literacy rate of 74.04 percent.

Most of the soils are made up of a combination of sand, silt, and clay. The formation of soil is primarily influenced by major factors such as climate, altitude and composition of bedrock etc. The land utilization classification reveals that 37.08% of the state geographical areas is under net area sown (60.43 lakh hectares), 22.63 % under forest (36.88 lakh hectares), 8.91% under current fallow lands (14.51 lakh hectares), 12.63% under land put non-agricultural uses (20.58 lakh hectares), 8.25 % under barren and uncultivable land (13.45 lakh hectares) and remaining 7.03% is under other fallow land.

Andhra Pradesh has huge oil & natural gas reserves. The state's Krishna-Godavari basin, spread over an area of nearly 52,000 sq km, has a total hydrocarbon resource base of 1,130 million metric tonnes.

2.2 Economic Parameters

2.2.1 GSDP/NSDP

Andhra Pradesh's Gross State Domestic Product (GSDP) for the year 2018-19 (Advance Estimates) at current prices has been estimated as Rs.933402 Crores as against Rs.809548 crores for 2017-18 (First Revised Estimates). The sectorial growth rates of GVA of Andhra Pradesh for 2018-19 at constant (2011-12) prices are Agriculture: 10.78%, Industry: 10.24% and Services sector: 11.09%. The Per Capita Income (NSDP) of Andhra Pradesh at current prices has registered a growth of 13.96 percent as it increased from Rs.1,43,935 in 2017-18 (FRE) to Rs.1,64,025 in 2018-19, as compared to the Per Capita Income of All India which has increased from Rs. 1,14,958 in 2017-18 to Rs. 1,26,699 (AE) in 2018-19.

2.2.2 Foreign Direct Investment (FDI) inflow & Investments

Andhra Pradesh has been one of the foremost states to have developed sector-specific policies. Forming industrial clusters and developing infrastructure, such as biotech parks, textile parks and hardware parks, has been the state's key strategy to attract investments in various industries. According to the Department for Promotion of Industry and Internal Trade (DPIIT), FDI inflows in Andhra Pradesh between April 2000 and March 2019 reached US$ 18.46 billion.

Natural resources, policy incentives and infrastructure in the state are favorably suited for investments in major sectors such as drugs and pharmaceuticals, biotechnology, IT and ITeS, mines and minerals, textiles, leather and tourism. Attracting investments in the IT sector is in focus.

A new industrial policy is geared at attracting foreign direct investments in India through manufacturing. It is hoped that the annual growth rate for the MSME sector attains a 12 to 15% sustainable growth. Foreign Direct investments in India topped US$1.74 billion by end of last year. A majority of this came from Andhra Pradesh and its vibrant economy. On the other hand, the services sector in Andhra Pradesh is estimated to have attracted Foreign Direct Investments in India of up to US$3.54 billion. The services sector in this region comprises of the financial and non-financial services. The telecommunications sector too, performs relatively well.

2.3 Agriculture

Andhra Pradesh is predominantly an Agricultural economy as agriculture is the most vital and sensitive sector of the state as agriculture is the main source of livelihood for nearly 60 percent of the population. Agriculture has been the chief source of income and main occupation for the state with 60% of population engaged in agriculture and related activities. Rice is the major food crop and staple food of the state. Other important crops are sugarcane, cotton, mango, tobacco, Maize, pulses etc. Four important rivers of India, the Godavari, Krishna, Penna, and Tungabhadra flow through the state, providing irrigation. Recently, crops used for vegetable oil production such as sunflower and peanuts have gained favour. Andhra Pradesh was among the very few states in the country which went in for the Green Revolution in rice cultivation in the 1970s.

The area under food grains is estimated to be 40.26 lakh hectares in 2018-19 as against 42.06 lakh hectares in 2017-18, showing a decrease of 4.27%. The total production of food grains in 2018-19 is estimated at 151.12 lakh tonnes while it was 167.22 lakh tonnes in 2017-18 showing a decrease of 9.63%. The cropping intensity for the year 2018-19 has marginally declined to 1.24 from 1.26 of the last year. The number of holdings has been increasing - from 76.21 lakh holdings in 2010-11 to 85.24 lakh in 2015-16. This huge rise in the number of holdings coupled with a decline in the area operated has contributed to a fall in the average size of the holding from 1.06 hectares in 2010-11 to 0.94 hectares in 2015-16. The “YSR RythuBharosa” Scheme to be implemented in the state from October 15th, 2019 will help the farming community in a big way. In a landmark decision, the state government has decided to facilitate “Crop Insurance Premium payment by the government itself instead of farmers for the entire notified area”.

2.4 Horticulture

Andhra Pradesh has changed their cropping pattern at a rapid rate and the horticulture sector is growing at a faster pace than agriculture, making Andhra Pradesh a major horticulture hub. The returns from

Horticulture per unit of land are higher as compared to Agriculture. Horticulture, as a climate resilient alternative involving less risk, assures higher income to farmers. In the context of global warming & climate change and increasing per capita income of middle class, this sector has more potential as food habits are changing and people are becoming more health conscious. The government is planning to expand the area under horticulture crops considerably. Incentives like extending 90% Subsidy on micro irrigation drip and sprinkle have dramatically improved the horticulture production significantly. In the state area under Horticulture crops is 17.62 Lakh Hectares with a production of 327.57 Lakh MTs. Andhra Pradesh stands at 1st position in productivity for Chillies, Cocoa, Lime, Oil Palm, Papaya and Tomato, 2nd in Cashew, Mango, Turmeric and Sweet Orange in India. An area of 1,25,317 Ha. was brought under perennial, non-perennial fruit and plantation crops. Micro-Irrigation implemented in about 2 lakh ha. during 2018-19, showed an increase of 8% achieved over previous year. Andhra Pradesh is the Second largest producer of silk in India. The total area under Mulberry in the State stands at 1,04,790 acres.

2.5 Irrigation

Irrigation development plays an important role in the agricultural production as rainfall is inadequate, uncertain and uneven in the state of Andhra Pradesh. The cropping pattern and the agricultural productivity in the state are greatly guided by irrigation. Irrigation Development not only correlates to Agriculture but also to other Socio-Economic aspects like industry, navigation, hydropower, pisiculture, water supply etc. The State is broadly divided into two agro-climatic zones. The Rayalseema zone, which is semi-arid and drought prone receives about 700 mm rainfall. The net sown area is only 38 per cent in this zone and the irrigation infrastructure is poor. The Coastal zone has more than 1000 mm rainfall and the climate is sub-humid. The soil salinity and floods are the limiting factors. The State has many rivers and lakes and there are 40 major, medium and minor rivers in the state of which 15 are interstate rivers. The State has prioritized in creation of Irrigation Potential. So far, 105.36 lakh acres of irrigation potential has been created up to March 2019 under major anicuts on Krishna, Godavari and Pennar rivers through projects like Nagarjuna Sagar, Telugu Ganga, Somasila, SRBC, Vamsadhara, Medium Irrigation projects and Minor Irrigation schemes.

2.6 Forest Resources

Andhra Pradesh state with its diversified topography ranging from the hills of Eastern Ghats and Nallamallas to the shores of Bay of Bengal supports varied ecotypes, which in turn support a rich diversity of flora & fauna. As per the forest records, the state ranks 9th in India having forest cover area of 37707

Sq. Kms which amounts to 23.54% of this forest area, the Very Dense Forest is 1957 Sq. Kms the Moderate Dense Forest is 14051 Sq. Kms, Open Forest is 12139 Sq. Kms Scrub Forest is 9560 Sq. Kms. Forest cover has been recognized as critical for a living environment as it influences the quality and quantity of air and water. While the tangible benefits like Timber, Bamboo, Fuel wood, Fodder, Non-Timber Forest Products etc. are quantifiable but the intangible benefits like maintenance of ecological balance, conservation of soil and moisture, regulating the water flow, sequestering carbon-dioxide from the atmosphere etc. are not quantified but are of great significance.

2.7 Fisheries

The State of Andhra Pradesh is endowed with highly diversified and potential water resources and offering immense scope for expansion of pisciculturer sector for socioeconomic growth of the State. It is one of the most promising sector and occupies a predominant place in the socio-economic development of the state as it contributes substantially to economic growth and income generation to lakhs of people. The sector utilizes the natural resources for generating rural employment, production of protein rich food, valuable contribution to GSDP and source of foreign exchange through sea food exports. The State ranks first in brackish water shrimp production, first in fresh water prawn production, second in fresh water fish production, second in total value of fresh water fish and fourth in marine fish production. The State contributes more than 65% of cultured shrimp produced in the country.

2.8 Industry

Industrial development is one of the major components of economic development of the State. Andhra Pradesh, the tenth largest State in India in terms of population, and seventh in terms of area, is endowed with rich natural resources & mineral wealth. The state has a population of 4.96 crore (as per Population Census 2011), accounting for 4 per cent of the country's population residing in 4.9 per cent of the country's geographical area. The State has accorded top priority to industrial and infrastructure growth, and intends to position the State as the most preferred destination for investors by providing favorable business climate, excellent infrastructure, good law and order, and cordial industrial relations. The Government has introduced various investor-friendly policies for different sectors to facilitate availability of resources, provide conducive industrial environment, develop state of-the art infrastructure, foster innovation and create employment opportunities. The State has already made an impact through its investor-friendly initiative by being ranked as the 2nd best state in the country on Ease of Doing Business as per a report by the World Bank.

Forming industrial clusters and developing infrastructure, such as biotech parks, textile parks and hardware parks, has been the State's key strategy to attract investments in various industries. Natural resources, policy incentives and infrastructure in the state are favourably suited for investments in major sectors such as drugs and pharmaceuticals, biotechnology, IT and ITeS, mines and minerals, textiles, leather and tourism. As of January 2019, the state had 19 operational SEZs across diversified sectors which include textiles and apparel, food processing, footwear and leather products, multi-product, pharma, IT SEZs etc. Seemandhra, comprising Rayalaseema and coastal Andhra, has most of the power projects of undivided Andhra Pradesh. Coal-based power plants are mostly located in the state due to proximity to the ports. As of February 2019, Andhra Pradesh had a total installed power generation capacity of 23,973.90 MW.

During 2018-19, 44 Large and Mega industrial projects have been established. Similarly, during this period, 10068 Micro, Small and Medium Enterprises were established. Visakhapatnam–Chennai Industrial Corridor (VCIC), is a key part of the East Coast Economic Corridor (ECEC), designed to complement the ongoing efforts of the Government of Andhra Pradesh (GoAP) to enhance industrial growth and create high quality jobs. Chennai-Bangalore Industrial Corridor (CBIC) is one of the mega infrastructure projects of Government of India which passes through the State with the main objective of increasing the share of manufacturing sector in the GDP of the country and to create smart sustainable cities which will have world-class infrastructure, convenient public transport power management and an efficient water and waste management system.

2.9 Information Technology

The State of Andhra Pradesh is poised towards creating a benchmark in Information & Communication Technology (ICT) endowed with a high quality state-of-the-art physical & communication infrastructure of international standards, harnessed human resources, and proactive business friendly policies of the Government. The IT sector is the backbone of the economy, and will continue to provide the thrust required to generate large investments and employment while also ensuring the delivery of citizen centric “good governance”. The Government is committed for making the state as a suitable destination for IT Services, Electronic Manufacturing /Assembling. The Government is helping the growth of IT in general.

2.10 Service Sector

Service Sector Mission is one of the seven missions constituted by the Government of Andhra Pradesh. The area under Service Sector mission is creating job opportunities by promoting tourism and information technology sectors thereby giving a thrust to tourism, hotel, real estate, banking, IT Services, transport and

logistics. Service Sector mission departments and sub-departments interact with other departments within the state and also with various departments of Government of India, external agencies such as Banks, other departments of state governments, private agencies and institutions for discharging various functions and delivery services. It is imperative for the economic growth of the state since every additional job in this sector contributes 3.8 times to GVA as compared to agriculture. Services sector provides an opportunity for shifting excessive and less productive work force out of the primary sector. Services has a share of 46% in State GVA.

Air transport and storage are other important growth engines that have been identified for promoting the services sector of Andhra Pradesh. Kadapa Airport has been made operational under the Regional Connectivity Scheme, and international operations are planned for commencement from Vijayawada and Tirupati airports in addition to Vishakhapatnam. Construction of Multi Modal Logistics parks (MMLP), and Cargo Terminal at the selected airports is underway, which shall promote trade (domestic/exports) and also create demand for services. Inland waterway works shall commence shortly, which shall not only provide seamless cargo movement at cheaper cost, but also create immense employment opportunities.

2.11 Power

Power sector is a critical infrastructure element required for the smooth functioning of the state economy. An efficient, resilient and financially robust power sector is essential for growth and poverty reduction. The availability of reliable, quality and affordable power helps in the rapid Agriculture and Industrial development and the overall economy of the state. It is one of the vital infrastructural inputs for the socioeconomic development of any nation, either in the form of finite resources such as coal, oil and gas or in renewable forms such as hydroelectric, wind, solar and biomass, or its converted form of electricity.

Andhra Pradesh is the fourth largest power generating state in the country and also has the largest hydro power generation capacity in India (Andhra Pradesh is on first position for installed hydro power generation capacity). The installed capacity in the Andhra Pradesh state is 24518 MW (up to 30/11/2019). During the year 2019-20, additional generation capacity of 1,600 MW of thermal power is expected to be commissioned.

Apart from the state sector, private players have considerable presence in Andhra Pradesh. Private power plants operating in the state use transmission lines of Andhra Pradesh Transmission Company (AP Transco) that looks after the trans-mission of electricity in the state. Due to its geographical location, the

power generated by all power plants is being fed to the Southern Grid, which is accessible to all states which are a part of the southern grid.

The Power scenario of the State has been explained in the subsequent chapters.

CHAPTER-3: POWER SCENARIO

CHAPTER - 3

3. POWER SCENARIO

3.1 Introduction

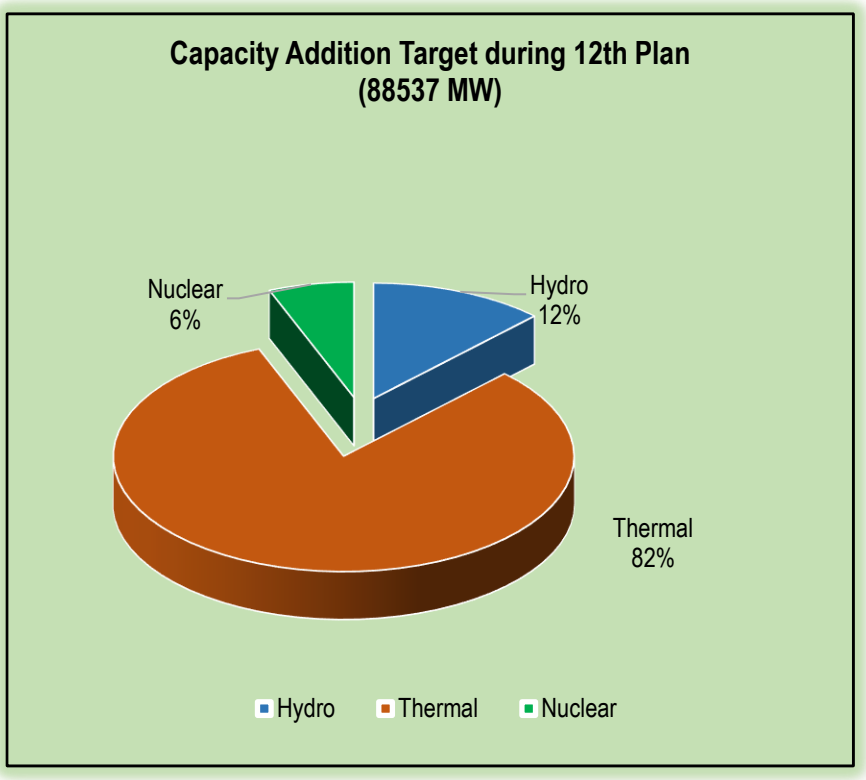
If India is to maintain high rate of growth and provide universal and sustainable access to electricity, the power sector needs to grow and reform faster in all the three constituent areas of generation, transmission and distribution. In the XI Plan there have been major slippages in capacity creation especially in the central sector. The primary impediments are uncertainty in fuel linkages, environmental clearances, land acquisition and shortage of equipment. Presently the electricity distribution network covers 98.75 per cent of the villages in India. Poor private sector participation, problems in obtaining clearances on the Right of Way and inadequate indigenous manufacturing capacities are the major bottlenecks in enhancing capacities. In the case of distribution, the large AT&C losses have discouraged private participation and prevented the state utilities from investing in the network.

8 percent GDP growth requires 6 percent growth in energy supply from all sources. The countries fossil fuel sources are limited and our import dependence is already high and as such, we need to push for renewable energy i.e. Wind, Solar, and Storage hydro. As per review carried out by CEA, as on 31.03.2017 the actual capacity addition during 12th five year plan (2012-2017), from conventional sources is 99209.5 MW (Thermal – 91730.5 MW, Hydro - 5479 MW and Nuclear - 2000 MW) against target of 88537 MW. This is about 112% of the target, but 55% of total capacity addition during 12th Plan has come from private sector. There has been considerable slippage against the capacity addition target in respect of Hydro (5418 MW) and Nuclear (3300 MW) during 12th Plan period.

As on 31.03.2017 India achieved a total installed capacity of 57,244.23 MW from Renewable energy source. The country has revised its renewable energy capacity target to 175 GW by the year 2021-22.

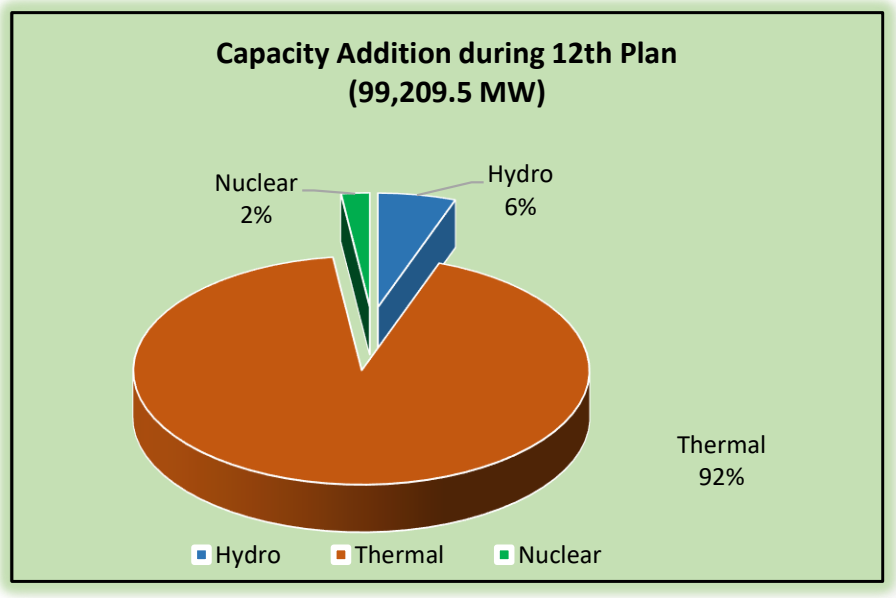
As per the 19th Electric Power Survey report, the projected peak demand is 226 GW and energy requirement is 1566 BU at the end of 2021-22 and peak demand is 299 GW and energy requirement is 2047 BU at the end of the year 2026-27.

Total energy savings due to implementation of various energy saving measures during the years 2021-22 and 2026-27 are estimated to be 249 BU and 337 BU respectively.



Source: Central Electricity Authority (CEA)

Fig.3.1 - Capacity Addition target during 12th Plan (Type wise)



Source: CEA

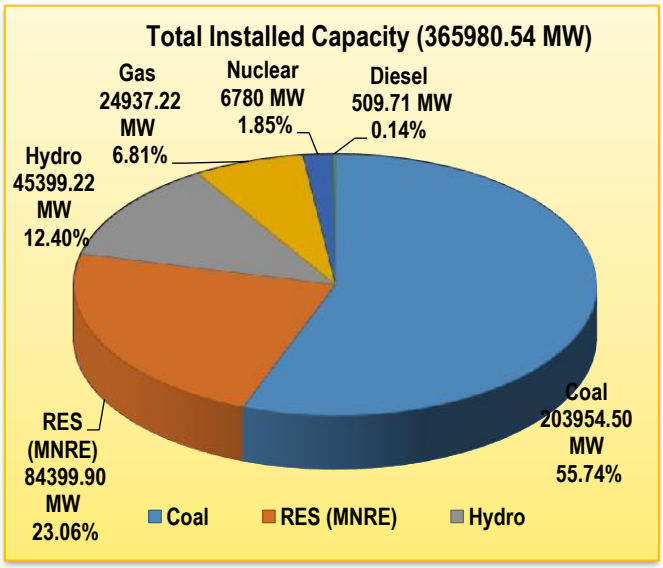
Fig.3.2 - Capacity Addition during 12th Plan (Type wise)

Considering the capacity addition (19th EPS. CAGR 6.18%) from Gas 406 MW, Hydro 6823 MW, Nuclear 3300 MW, RES 117756 MW and likely retirement of 22716 MW (5927 MW-old and inefficient units + 16789 MW completing 25 years by 2022 and without FGD space) of coal based capacity during 2017-22, the study result reveals that coal based capacity addition of 6445 MW is required during the period 2017-22. However, a total capacity of 47855 MW coal based power projects are currently under different stages of Construction and are likely to yield benefits during the period 2017-22. Thereby, the total capacity addition during 2017-22 is likely to be 176140 MW.

Considering the demand projections for the year 2026-27, as per the 19th EPS, coal based capacity addition of 47855 MW already under construction for benefits during 2017-22, committed capacity addition of Nuclear 6800 MW, Hydro 12000 MW, RES 100000 MW and likely retirement of 25572 MW of coal based capacity (which will be completing more than 25 years of age by 2027) during 2022-27, the study results reveal that capacity addition of 46420 MW is required during the period 2022-27. This capacity addition required during 2022-27, as shown in the results is, in fact, the peaking capacity requirement to be met in the grid. This capacity requirement can be met from any conventional source of energy but preferably from peaking power plants like Hydro, Gas or Energy Storage Devices.

3.2 Installed Generating Capacity in India

The mode wise total installed capacity in the country as on 31st November, 2019 (as per CEA) is 365980.54 MW and given below:



Source: CEA

Fig.3.3 - Total Installed Generating Capacity as on 31st November, 2019

The Southern Region has an installed capacity of 109236.03 MW as on 31st November, 2019 consisting of 46182.02 MW thermal, 11774.83 MW hydro and 41051.86 from renewable energy sources. The Southern Region faced energy shortage of 0.1% and peaking shortage of 0.1% during April, 2018 to March, 2019.

The hydro installation of 11774.83 MW in overall installation of 109236.03 MW in Southern Region is only 10.78% which is much below the optimum hydro thermal mix of 40:60. Thus there is an urgent need to take up more storage based hydro projects with an aim to achieve optimum hydro thermal mix in the region.

The total energy requirement in the country during 2018-19 was 1274595 Million Units (MUs) as against 1213326 MUs during the previous year, registering an increase of 5%. The total energy supplied in the country during 2018-19 was 1267526 MUs as against 1204697 MUs during the previous year, registering an increase of 5.20%.

The energy not supplied during the year 2018-19 was 7070 MUs (0.6%) against 8629 MUs (0.7%) during the previous year. The peak demand during the year 2018-19 was 177022 Mega Watt (MW) as against 164066 MW during the previous year, registering an increase of 7.9%. The peak demand met during 2018-19 was 175528 MW as against 160752 MW during the previous year, registering an increase of 9.2%. The demand not met during the year 2018-19, decreased from 3314 MW (2.0%) to 1494 MW (0.8%) as compared to previous year. The power supply position in the Country and in the Southern Region are given in the **Table 3.1** and **Table 3.2**

Table 3.1
Power Supply Position (Energy & Peak) in the Country

Energy				
Year	Energy Requirement (MU)	Energy Supplied (MU)	Energy not Supplied	
			(MU)	(%)
2014-15	1068923	1030785	38138	3.6
2015-16	1114408	1090850	23558	2.1

2016-17	1142928	1135332	7596	0.7
2017-18	1213326	1204697	8629	0.7
2018-19	1274595	1267526	7070	0.6

Peak				
Year	**Peak Demand (MW)**	**Peak Met (MW)**	**Demand not Met**	
			(MW)	**(%)**
2014-15	148166	141160	7006	4.7
2015-16	153366	148463	4903	3.2
2016-17	159542	156934	2608	1.6
2017-18	164066	160752	3314	2.0
2018-19	177022	175528	1494	0.8

Source: Executive Summary on Power Sector October'2019, CEA

Table 3.2

Power Supply Position (Energy & Peak) in the Southern Region for April, 2019- October, 2019

Energy					**Peak**			
State/ Region	**Energy Requirement (MU)**	**Energy Supplied (MU)**	**Energy not Supplied**		**Peak Demand (MW)**	**Peak Met (MW)**	**Demand not Met**	
			(MU)	**(%)**			**(MW)**	**(%)**
Andhra Pradesh	38340	38302	38	0.1	10183	10170	13	0.1
Telangana	37111	37109	2	0.0	11703	11703	0	0.0
Karnataka	40113	40111	2	0.0	12700	12688	12	0.1
Kerala	15238	15201	37	0.2	4487	4300	186	4.2
Tamil Nadu	65554	65551	3	0.0	15727	15668	59	0.4
Puducherry	1768	1767	1	0.1	470	470	0	0.0
Lakshadweep	27	27	0	0	8	8	0	0
Southern Region	**198124**	**198040**	**84**	**0.0**	**49218**	**49103**	**115**	**0.2**

Source: Executive Summary on Power Sector October'2019, CEA

3.2.1 Advance National Transmission Plan for Year 2021-22

Regarding the renewable generation capacity by 2012-22, it was brought out that the RES (only wind & solar) capacity would increase from 26 GW to 160 GW (solar 100 GW and wind 60 GW) during the same period.

As the wind and solar may not give benefit during peak load (6-8 pm) availability may be taken to zero. From the analysis it appeared that Northern & Southern region would still be in deficit and the other region i.e. Eastern, Western and North Eastern regions would be in surplus. The NR may need to import 24000 MW (during years of monsoon failure) and SR may need to import about 14600 MW in 2021-22. This analysis was based on assumption that 117 GW generation I/C would be added during the period of Nov'15 to March'22. Wind and Solar would not contribute at all during NR and SR peak load hours. Gas plants would give only 40% during peak hours etc.

3.2.2 Generation Addition up to 2021-22

Table 3.3

Capacity Addition Targets and Achievements in the 12th Plan

Sector	Thermal		Hydro		Nuclear		Total	
	Target	Ach.	Target	Ach.	Target	Ach.	Target	Ach.
Central	14878	15869	6004	2584	5300	2000	26182	20453
State	13922	22201	1608	2276	0	0	15530	24477
Private	43540	53661	3285	619	0	0	46825	54280
All India	**72340**	**91730**	**10897**	**5479**	**5300**	**2000**	**88537**	**99209**

(Figures in MW) Source: Executive Summary on Power Sector October'2019, CEA

3.2.3 All India Electrical Energy Requirement, Peak Electricity Demand & Electrical Energy Consumption Projections for 2016-17 to 2026-27

The electricity consumption on all India basis during the year 2016-17, 2021-22 and 2026-27 has been assessed as 921 BU, 1300 BU and 1743 BU respectively. The electrical energy requirement on all India basis during the year 2016-17, 2021-22 and 2026-27 has been 1160 BU, 1566 BU and 2047 BU respectively. The peak electricity demand as 162 GW during the year 2016-17; 226 GW during 2021-22 and 299 GW 2026-27. The electrical energy consumption, T&D losses, electrical energy requirement, peak electricity demand and derived load factor for the years 2016-17, 2021-22 and 2026-27 is summarized in successive tables.

Table 3.4

Peak Electricity Demand at Power Station Bus Bars (MW)			
Region	**2026-27**	**2031-32**	**2036-37**
Northern Region	97182	118844	144161
Western Region	94825	119277	142355
Southern Region	83652	104900	128655
Eastern Region	35674	42968	51420
North-Eastern Region	6710	8373	10007
Andaman & Nicobar Islands	129	153	177
Lakshadweep	13	16	18
All India	**298774**	**370462**	**447702**

Table 3.5

Electrical Energy Consumption (MU)			
Region	**2026-27**	**2031-32**	**2036-37**
Northern Region	510941	646737	794572
Western Region	543036	685483	825499
Southern Region	477932	595712	728039
Eastern Region	183157	226116	275804
North-Eastern Region	27384	37598	47587
Andaman & Nicobar Islands	518	660	802
Lakshadweep	67	79	93
All India	**1743036**	**2192305**	**2672302**

Source: 19th EPS, CEA

3.3 Power Sector in Andhra Pradesh

3.3.1 Introduction

Power sector of Andhra Pradesh is divided into 4 categories namely Regulation, Generation, Transmission and Distribution. Andhra Pradesh Electricity Regulatory Commission (APERC) is the regulatory body. APGENCO deals with the electricity production and also maintenance, proposes new projects and upgrades existing ones as well. The APGENCO also set up a Special Purpose Vehicle (SPV), named as Andhra Pradesh Power Development Company Limited (APPDCL), a joint venture company of APGENCO (with 50% equity) and IL&FS (50% equity) to set up Krishnapatanam thermal power project (2x800 MW).

APTRANSCO is set up for transmission of power. Power distribution in the state is divided into two divisions, namely Eastern Power Distribution Corporation Limited (EPDCL) and Southern Power

Distribution Corporation Limited (SPDCL), which distributes the power to the households and the industries. APGENCO, APPDCL, NTPC and other private firms contribute to the generation of power in the state of Andhra Pradesh.

3.3.2 Existing Power Scenario of Andhra Pradesh

Generation of Electrical Energy

The total installed capacity of the Andhra Pradesh state as on 30th November, 2019 is 24518.36 MW comprising of 14643.82 MW thermal power, 1673.6 MW hydro Power and 8073.67 MW renewable energy sources which includes central and private sector also.

Demand and Supply Scenario

The energy requirement of Andhra Pradesh during FY 2016-17 was 54673 MU and in the FY 2020-21 it would be 78540 MU as per projection made in the 19th EPS of India due to rapid increase in power demand for all types of present and future customers (Domestic, Commercial, Irrigation, Industries, Railway traction and others).

Table 3.6(A)
Southern Region & Andhra Pradesh Electrical Energy Requirement (MU) at power station bus bars (Utilities)

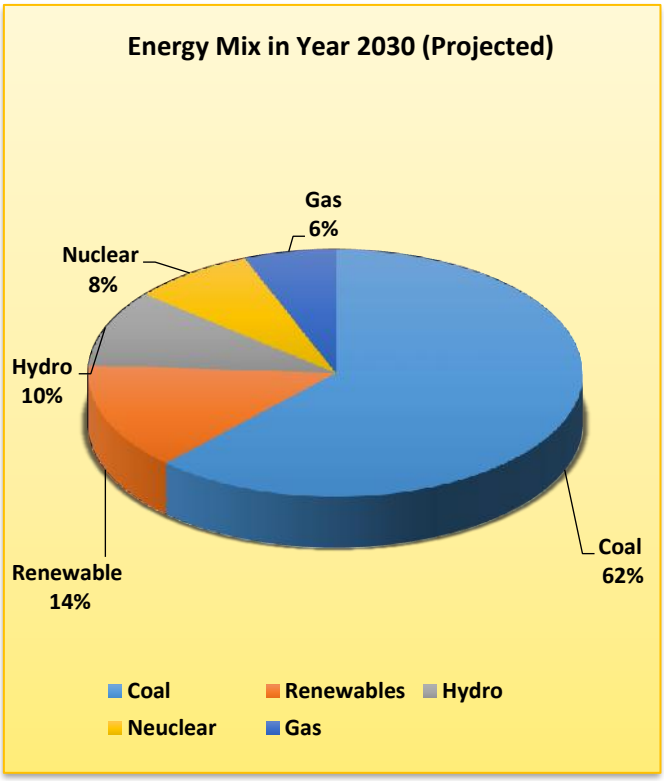
State/Region	2016-17	2021-22	2026-27	2031-32	2036-37
Andhra Pradesh	54673	78540	111485	145148	180190
Southern Region	307047	420753	550992	680149	824657

Source: 19th EPS, CEA

Table 3.6 (B)
Southern Region & Andhra Pradesh Peak Electricity Demand (MW) at power station bus bars (Utilities)

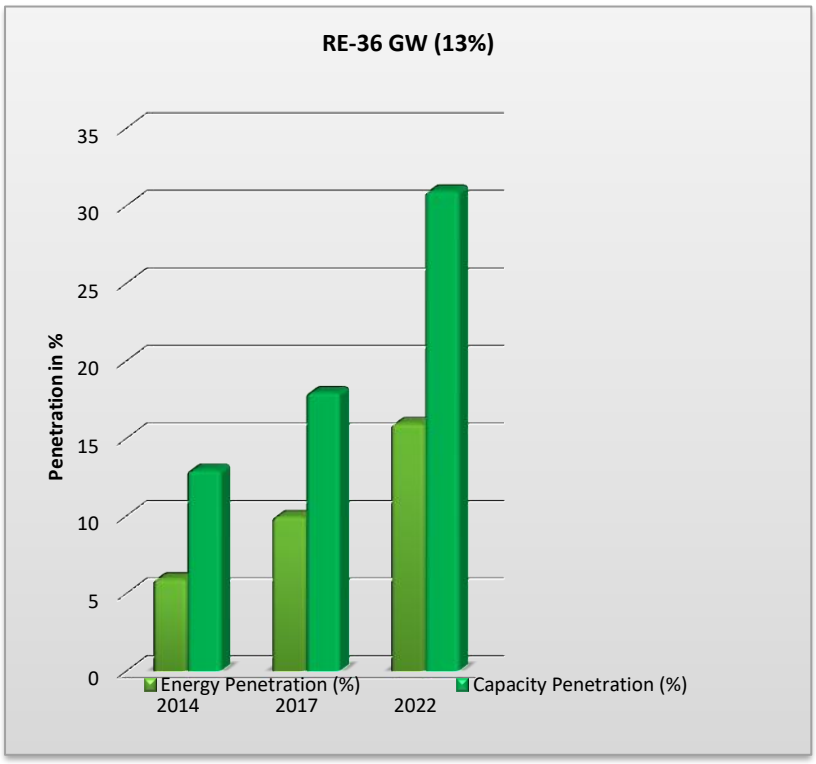
State/Region	2016-17	2021-22	2026-27	2031-32	2036-37
Andhra Pradesh	8245	11843	16820	23223	29661
Southern Region	44782	62975	83652	104900	128655

Source: 19th EPS, CEA



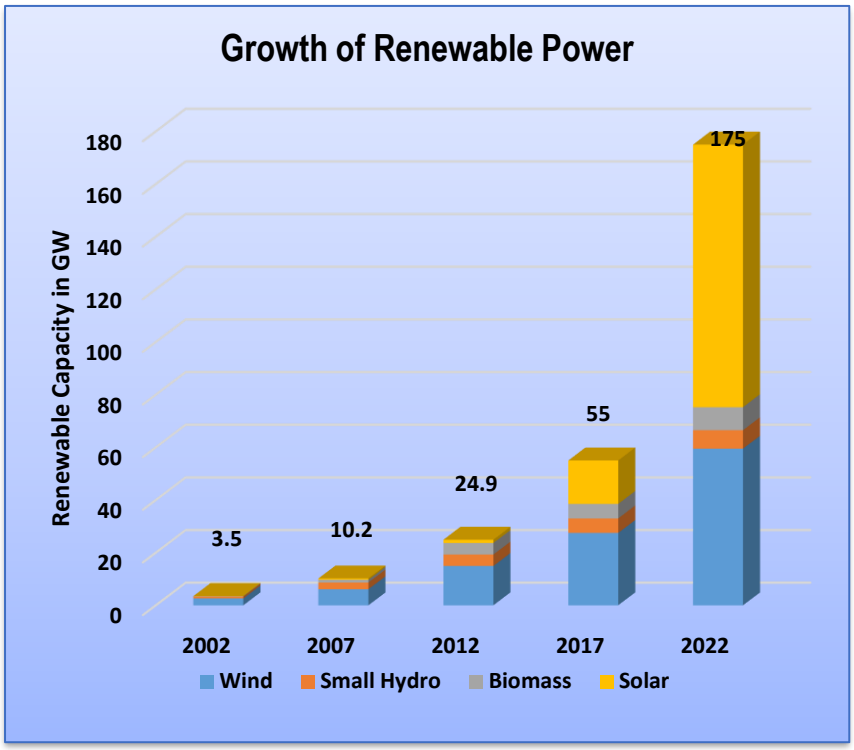
Source: Central Electricity Regulatory Corporation (CERC)

Fig.3.4 - Energy Mix for Electricity Generation of India in Year 2030 (Projected) Capacity Addition



Source: CERC

Fig.3.5 - Energy and Capacity Penetration



Source: Ministry of New and Renewable Energy (MNRE)

Fig.3.6 - Exponential Growth of Renewable Energy.

3.4 Importance of Hydro in Present Scenario

The current development profile and trends in generation capacity addition in India have resulted in the following aspects:

- **Skewed development pattern between different generation technologies:** The current portfolio of installed capacity of 365980.54 MW as on 30.11.2019 is dominated by thermal power with around 56% share. Hydro, with an installed capacity of 45399.22 MW has a share of around 13%. Adequate diversity in generation asset base has not been maintained with growth in hydro assets not being concomitant with growth in the thermal asset base. This also impacts the long-term least cost development pattern with over reliance on 25-year thermal plants vis-à-vis more than 40 year hydro assets.
- **Inadequate peaking and quick response capability:** While regional grids have been integrated and frequency regimes have been streamlined, the country faces lack of assets capable of meeting peaking deficits and with quick response characteristics. For meeting peak requirement and to mitigate the variability due to renewable energy sources of the order of 175 GW by 2022

and with the shortage of gas, the peak and the balancing requirement is to be primarily met by Hydro Electric Projects.

- **Sustainable low carbon development:** While India is considering a low carbon strategy and actively considering focusing on Energy Efficient Renovation & Modernization to utilize existing assets, the low carbon strategy can be fostered further with a higher thrust on green capacity additions via hydropower development. These factors necessitate renewed emphasis on 'responsible hydropower development' to promote economic growth. Hydro's critical role in sustainable development and energy security for the country is based on the elements of sustainability, availability and affordability.

(Ref: - National Electricity Plan January 2018, CEA)

3.5 Pumped Storage Plants - Best Friend of Electricity Grid

While many forms of energy storage systems have been installed globally, Pumped Storage Plants (PSP) are playing an increasingly important role in providing peaking power and maintaining system stability in the power system of many countries. Pumped storage technology is the long term technically proven, cost effective, highly efficient and operationally flexible way of energy storage on a large scale, providing energy balancing for intermittent and variant energy generated by solar and wind.

PSPs improve overall economy of power system operation, increase capacity utilization of thermal stations and reduce operational problems of thermal station during light load period. The other advantages of pumped storage development are availability of spinning reserve at almost no cost to the system and regulating frequency to meet sudden load changes in the network. PSPs have the ability to provide ancillary benefits such as flexible capacity, voltage support and Black-start facility etc. Pumped storage technology has advanced significantly since its original introduction and now includes adjustable speed pumped turbines which can pump water at different speed with different load. PSPs has the technology, which can quickly shift from motor, to generator, to synchronous condenser modes, for easier and more flexible operation of the Grid.

Out of 96,524 MW of pumped storage potential identified in India by CEA at 63 sites, at present 9 nos. pumped storage schemes with aggregate installed capacity of 4786 MW are in operation out of which only 5 nos. plants with aggregate installed capacity of 2600 MW are being operated in pumping mode. The remaining 4 nos. plants with an installed capacity of about 2200 MW are not operating in pumping mode mainly because the 2nd reservoir is either under construction or the same has not been constructed.

Efforts are being made to complete and operationalize the pump storage projects not running in PSP mode by resolving the issues.

3.6 Issues and Way Forward for Pumped Storage Hydro Projects

- Since Pumped storage schemes use energy for pumping operation, commercial justification of peak energy produced from these plants pose problem. It is therefore desirable that separate regulation for peak energy may be envisaged.
- Regulatory treatment to Pump Storage schemes and market design is very critical for commercial viability of these plants as pricing rules should fully capture benefits of PSP and reward such assets for the full range of services provided by them to the Power system.
- The Pumped storage schemes should be considered as Grid Element instead of Energy Generation Source and may be funded from Power System Development Fund (PSDF) or National Clean Energy and Environment Fund (NCEEF).
- Water and Water Power is state subject. State Governments should be encouraged to allocate the identified pumped storage schemes to prospective developers for implementation.
- Some of the identified schemes, may be located in areas which have been declared as Wild Life Sanctuaries. The State/Central Governments are required to take necessary action to de-notify the areas required for development of pumped storage schemes involving Wild Life Sanctuaries.
- In case, it is possible to locate a pumped storage scheme where upper/lower reservoir is already existing/under construction, it would be more cost effective and easily implementable.

(Ref: - CERC)

3.7 Regulatory Issues and Challenges

- **Grid Stabilization and security** - Large Capacity addition Renewable Generation and dealing with its variability
- **Technical Mechanism** - Backing down of renewable and need for flexible operation of conventional generation
- Difficult sites and Long gestation period
- High Capital cost of storage based Pumped Storage Plants and resultant high tariffs
- Poor Financial health of State Discoms

- Lack of Market Mechanism
- Lack of Ancillary Services
- Competition from other conventional sources

(Ref: - CERC)

3.8 Variability & Uncertainty of RES

- Renewable Energy Sources (RES) such as wind and solar power are variable and uncertain in nature.
- They are not able to generate electricity on demand and their power output fluctuate with weather conditions (such as wind speed, wind direction, temperature, rain, cloud cover and humidity)

3.9 Necessity and Justification

It is observed that expansion of estimated power requirement during the period of 13th five year plan (1st April 2017 to 31st March 2022) and estimated power requirement in 2030, NREDCAP can take part in this integration of power generation of the country.

As per forecast of 12th and 13th (National 5 Year Plan), the Electrical Energy Requirement of Southern Zone for the period 2016-17 is estimated to be 307047 MU and for the period 2021-22 is estimated to be 420753 MU. Requirement of Peak Electricity Demand at power station Bus bars has been estimated as 44782 MW for the period 2016-17 and 62975 MW and for the period 2021-22.

As per review of forecast of all India and state wise electrical energy consumption (MU) and CAGR of Actual and Forecast, peak electricity demand in Southern Region will increase to 62975 MW in 2021-22 from 44782 MW in 2016-17. Accordingly, in Andhra Pradesh peak electricity demand in 2021-22 will be 11843 MW against 8245MW in 2016-17. Increase of generation of NREDCAP is needed to cope up with the forecast of demand as stated above. Installation of Pumped Storage Project is suitable according to the present trend of world power scenario to meet up therefore peak demand as well as to avoid use of fossil fuel and to avail the opportunity of god gifted geological condition.

To maintain Indian standard frequency 50 cycles/sec and Grid balancing by generation of power or drawl is very much effective with Pump Storage Project Projects. There is a big scope to keep up this ratio with the installation of a Pump Storage Project as well as to add generation according to need of the grid which will ensure the active participation in expansion of power generation of the country in coming years.

Pump Storage project helps the grid (frequency balance) by adding power by generation in peak demand and draw power during off peak for pumping. It helps the thermal power stations to generate more power in off peak by drawl of power for pumping of pumped storage project which helps to relieve the back down of thermal power stations, reduce costly oil support, minimize the breakdown, and ultimately improve the PLF of Thermal Power Stations.

From economic point of view, the pumped storage project is viable as the rate of energy is different at different time of the day (Table 3.21) though it draws more power during pumping rather than generation and efficiency is more than 75%. Energy charges also varies depending on frequency, during off peak demand when frequency has the tendency to be higher, rate of energy becomes lower which reduces the cost of pumping power.

If a big Solar project is connected with grid, frequency of the grid may change due to its sudden variation of generation due to its natural variation like, cloud, rain, storm etc. It is a hard task for Thermal power station to cope up the grid balance due to sudden change in solar generation, but costlier variable speed machine instead of fixed speed machine in the pumped storage project has the scope to cope up this variation within millisecond.

Proposal for installation of different Pumped Storage Schemes are very much essential to fulfil peak power demand and justified in consideration with the requirement of excess 18193 MW peak electricity demand at Southern Zone in 2021-22 in comparison to 2016-17.

Table 3.7

List of Mini Hydel Power Projects to be executed

Sl. No.	Name of Developer	Location	Capacity (MW)
1.	M/s.Suryachandra Synergetic India (P) Ltd.	Ongole Branch canal, Prakasam district	1.70 1.70
2.	M/s Krishnapriya Power (P) Ltd.	Mothugudem (V) East Godavari District.	4.00
3.	M/s Sardar Power Ltd.	Garugubilli (M) Vizianagaram district.	1.00
4.	M/s A.P. Tribal Power Com Ltd.	Pinjarikonda(V) Addathigala (M),East Godavari Dist	1.20

5.	M/s A.P. Tribal Power Com Ltd.	Mitlapalem (V) Addathigala(M),EGDt	1.20
6.	M/s Sri Paramma Thalli Mini Hydro Power Projects Pvt Ltd.	Dandigam(V), Salur Mandal, Vizianagaram district	5.00
7.	M/s Sri Helamba Hydro Power Projects (P) Ltd.	Near bridge on State High way Rampachodavaram(V), E.G.Dist	6.00
8.	M/s Vidya Bharathi Power Systems (P) Ltd.	Gundlakamma Vagu in Guntur district	2.00
9.	M/s Dhenu Energies Pvt Ltd.	Madhavaram, Velugodu (M),Kurnool dist	3.80
10.	M/s Mitra Energy Pvt Ltd.	Bandi Athmakur (V&M),Kurnool dist	2.60
11.	M/s Kurnool Energy (P) Ltd,	Chapirevula (V), Kurnool Dist.	3.40
12.	M/s Sri Venkata Krishna Power Pvt ltd.	Pinneli Water Tank, Pinneli (V), Machavaram(M) Guntur dist.	1.50
13.	M/s Esteem Power Pvt Ltd.	Darsi Mandal, Prakasam dist	1.20
14.	M/s Rank Power Pvt ltd.	Vempenta(V) Velugodu(M) Kurnool Dist	7.20
15.	M/s Balaji Energy Pvt Ltd	Somasila Reservoir, Nellore District (Additional capacity)	8.00
16.	M/s Balaji Energy Private Limited,	Somasila Reservoir in Somasila Village, Ananthasagaram Mandal, Nellore	3.00
17.	M/s Nagavaram Power System Private Limited	Bandi Atmakur (M), Kurnool District.	1.50
18.	M/s Victory Power Systems Pvt Ltd.	Velugodu (V&M), Kurnool District	9.00
19.	M/s. Tungapadu Power Pvt. Ltd.	Venkatabhairipuram Village, Makkuva(M), Vizianagaram (D)	3.50
20.	M/s Sindhu Power Systems Pvt Ltd.	Bayyaram Village, Guntur District	2.80
21.	M/s Kandaleru Power Company Ltd.	Kandaleru Reservoir, Rapur (V), Nellore District	9.00
22.	M/s Mohanaroopa Power Projects (P) Ltd.	Thonam Village, Salur Mandal, Vizianagaram District	12.00

23.	M/s Raji Power (P) Ltd.	Thallapalli (V), Macherla (M), Guntur District	4.00
		Total	**96.30**

Source: NREDCAP

CHAPTER-4: HYDROLOGY

CHAPTER – 4

4. HYDROLOGY

4.1 Objective of the Study

The overall objective of the hydrological study is to assess the water availability at the proposed pumped storage project site based on available hydrological data and design flood studies for various return periods at the proposed project site.

4.2 Present Study

The present study aims to utilize the existing Gandikota Reservoir (Live Storage capacity 671.28 MCM) on Pennar River together with a proposed new storage reservoir of 4.67 MCM as live storage capacity. This proposed reservoir shall be made by excavating a pit/making a bund to meet the storage requirement between an El. 470 to El. 490. The Location of the proposed upper reservoir is N- 14° 49' 47.28" E- 78° 13' 53.23". The proposed scheme would re-circulate the water diurnally between upper and lower (existing) storage reservoir, by installing reversible turbines, which would work both under pumping and generating mode.

The capacity of the proposed reservoir is only 0.68 % of existing lower reservoir. Even this water requirement is not of consumptive in nature and the same will be recirculated daily. Since the existing Gandikota reservoir is meeting its present demand, the only new addition under proposed pumped storage scheme shall be one-time requirement of 4.67 MCM only. Thus, its impact on existing demands of Gandikota reservoir shall be minimal. However, an estimate has been made in the present study to identify the time required (by lower reservoir) for meeting additional 4.67 MCM of water required for upper reservoir

4.3 Water Availability

A long-term runoff data at the project site or in nearby region is not readily available. The runoff factor method has been used to assess the water availability at the lower reservoir (existing) site for meeting the additional requirement of 4.67 MCM. Under present study, flows are assessed using the rainfall data from 1901 to 2016, which is available in a 0.25-degree x 0.25-degree format from the IMD. The same have been procured and monthly rainfall from 1901 to 2016 assessed. Subsequently 90% and 50% dependable annual rainfall assessed together with its dependable year and monthly rainfall.

Since no observed site-specific run-off data is available, the monthly dependable runoff have been estimated with the following assumptions

1) The runoff dependable year corresponds to the rainfall dependable year i.e. both dependable year rainfall and runoff year are same.
2) Since no site-specific run off is available hence a runoff factor of 0.49 has been considered to convert rainfall into runoff. This factor has been estimated based on similar study in the region.
3) The assessed monthly runoff (in mm) have been utilised to estimate the 90% and 50% dependable annual flow (MCM) at existing GANDIKOTA reservoir. The same is attached as **Annexure-4**
4) The evaporation loss has been assumed as 10 % of annual inflow.
5) The filling time required to meet 5.14 MCM (4.67 x 1.1) of water needed for recycling operation has been estimated accordingly

The 90% and 50% dependable flows at Lower Reservoir(existing) project site are as under: -

50% dependable Year = 1928
90% dependable Year = 1969

50% dependable flow = 5820.11 MCM
90% dependable flow = 4090.34 MCM

Filling Time: As stated above, the 90% dependable flow is 4090.34 MCM and the quantity of water required to fill the upper reservoir is only 5.14 MCM. As the water demand is very less as compared to water availability hence the filling time required for meeting 5.14 MCM of water by Lower Reservoir(existing) is insignificant and the same may be achieved with not much of a problem

4.4 Design Flood

In the preliminary stage no design flood studies have been carried out as the Lower reservoir is existing. In addition, the proposed upper reservoir entails construction of a small reservoir by excavating a small pit / making a bund only not on any existing river or nala. Hence the no design flood studies have been carried out for Upper reservoir also. However, detailed study will be carried out at FSR/DPR Stage.

4.5 Sedimentation

The lower reservoir is existing and under operation, hence sediment studies is not required. The proposed Upper reservoir is not situated on any river/nallah as such sediments are not likely to enter and accordingly sediment studies are not needed at this stage. The studies shall be carried out at FSR/DPR stage if needed.

4.6 Conclusion and Recommendations

In line with the scope of work and time line available, the preliminary data as available in respect of hydrology and meteorology were collected from CWC, IMD etc. The data obtained from thereof is preliminary. In the view of this, it is recommended that the project authorities may initiate collection of available hydrological data at the site and also in the region at FSR/DPR stage.

The Gandikota reservoir is an existing reservoir having gross storage capacity of 26.84 TMC (759.6 MCM). It is proposed to utilize existing Gandikota water to fill the upper reservoir. Additional 5.14 MCM of water is required to fill the proposed upper reservoir. The additional water thus required at Gandikota existing lower reservoir would be filled/met in one monsoon season only. Once the upper reservoir is filled the water would be recycled between upper and lower reservoir without any consumptive use. As such the proposed project would not affect the existing water balance in the lower reservoir, however this study further requires detailed analysis of water availability. The same may be carried out at FSR/DPR stage.

Annexure - 4

Annexure- 4

90% & 50% Dependable Flows

CA=19197 Sq.km

Sr.no.	Project Site		units	dependability	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Gandikota	Rainfall	mm	90%	1969	0.00	0.00	0.00	1.15	60.84	30.02	65.38	97.98	15.43	114.86	28.73	24.22	438.60
				50%	1928	0.00	87.10	0.00	4.69	4.43	120.88	50.00	144.07	99.61	112.30	0.00	0.99	624.08
		Runoff	mm	90%		0.00	0.00	0.00	0.56	29.55	14.58	31.76	47.60	7.49	55.80	13.96	11.77	213.07
				50%		0.00	42.31	0.00	2.28	2.15	58.72	24.29	69.99	48.39	54.55	0.00	0.48	303.18

CHAPTER-5: GEOLOGICAL STUDIES

CHAPTER - 5

5. GEOLOGICAL STUDIES

5.1 Introduction

The proposed Gandikota Pumped Storage Project is located in Kadapa district, Andhra Pradesh, India. Kadapa falls in toposheet no. 57J and the project area falls in the Lat. N 14° 49' 47" & N 14° 48' 28" and Long. E 78° 13' 53" & E 78° 15' 5" **(Fig-5.1)**. The proposed project envisages utilization of water from an artificial bund type reservoir proposed as upper reservoir, which will be created by excavating a Pit to divert the water through an Intake-HRT-Pressure shaft to an underground powerhouse to generate 600MW of power by utilizing gross head of 268.0m

The Full Reservoir Level of existing Gandikota reservoir (Lower Reservoir) is at El. 212m and Dead Storage level at El.202.9m. An artificial Reservoir is proposed as upper Reservoir which is constructed as bund type Reservoir at Elevation-470.0m. The proposed project will generate 600 MW of power by utilizing net design head of 269.87 m.

Fig.5.1. Google Earth image showing the proposed project area of GANDIKOTA PSP

The water from Power House will be diverted through a TRT and will be stored in an existing lower reservoir. The water will be pumped back to the upper reservoir through TRT-Reversible Turbines-pressure shaft-HRT to upper reservoir in off peak hours.

Kadapa district is the southern district of Andhra Pradesh. It is bordered by Chittoor district in the South, Kurnool and Prakasam districts in the north, Nellor district in the east and Anantapur district of Andhra Pradesh in the South.

The main aim of this report is geological feasibility study of the project components using District Resource Map of GSI for preparation of PFR and to formulate FSR/DPR stage investigation in future.

5.2 Regional Geomorphology and Geology

The district is mainly drained by the Penner River and its major tributaries like Cheyyeru and Kunderu and Sagileru. The southern granitic terrain is drained by Mandvi River, a tributary of Cheyyeru River. The drainage is parallel to sub-parallel in nature and controlled by structure. Numerous straight courses flow along the synclinal axis, litho-contact zones, faults/ major discontinuity zones.

The southern part is mainly comprising of pediplain- pediment complex with residual hills from granitic gneisses and structural ridges represented by dykes traversing ENE-WSW and NNW-SSE directions. There is an alternate sequence (Hogbacks) made up mostly by highly resistant quartzites and low lying structural valleys made by shales and dolomitic limestones. At places, owing to the resistance and low dipping angles these quartzites developed into plateaus.

In the eastern segment belongs to the Nallamlai hills ranges where steeply dipping structural ridges comprises of quartzites with interidge low area known as “structural valleys’ where less resistant Cumbum Shales and Phyllites are present.

The oldest rocks in the area belongs to mainly late Archaean or late Proterozoic age which are succeeded by rock of Dharwarian age and both are traversed by Dolratite dykes as intrusive. The major part of the Cuddapah district is occupied by Cuddapah basin, which is a huge depression formed over the denuded surfaces of older rocks extending into neighboring districts. The Archaean comprises the Peninsular Gneissic Complex of represented by granite, granite gneiss, granodiorite and migmatite. The Cuddapah Supergroup of rocks comprising of Papaghni, Chitravati and Nallamalai groups oocur to the east and north of the Archaean and Dharwar and occupy the major portion of the district. Mainly meta-sedimentary rocks comprising of Quartzite, conglomerate, shale, chert, limestone, slate with phyllite are the major types of rocks found in these areas.

A series of NW-SE, NE-SW & E-W trending lineaments (shear, Fault) are also present in the area as reflected on District Resource Map of GSI on 1:2,50000 scale **(Plate-5.1).**

5.2.1 Seismicity

Gandikota Pumped Storage Project is located within meta-sedimentary terrain comprises of Quartzite, shale, massive and flaggy limestone of Upper Proterozoic age. The area falls under seismic zone-II (**Fig.5.2**) as per Seismic Zonation Map of India (IS: 1893-2002, Part-1).

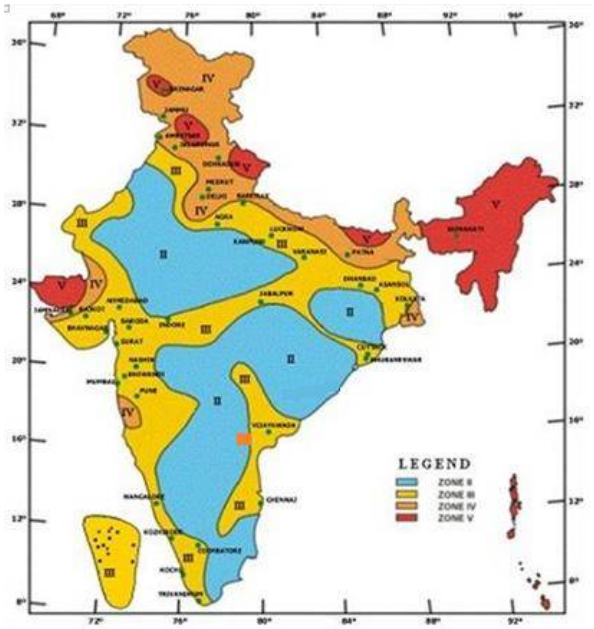


Fig.5. 2. Seismic Zonation Map of India showing project area

Both deterministic and probabilistic approaches for evaluation of design ground motion for a project site require a comprehensive database on past earthquakes in the region of the project. It is proposed to consider the seismic design parameters of the existing Gandikota Lower dam. The analysis of seismicity of Gandikota PSP is to be carried out to determine the detail seismic design parameter to be undertaken in the DPR stage. These studies are to be carried out following the guidelines of NCSDP. The project area lies in seismic Zone-II as per the Seismic Zonation Map of India (IS: 1893-2002, Part-1). The seismo-tectonic map of the area (SEISAT-34) from Seismotectonic Atlas of India and its Environ, 2000, GSI is enclosed as **Fig.3.**

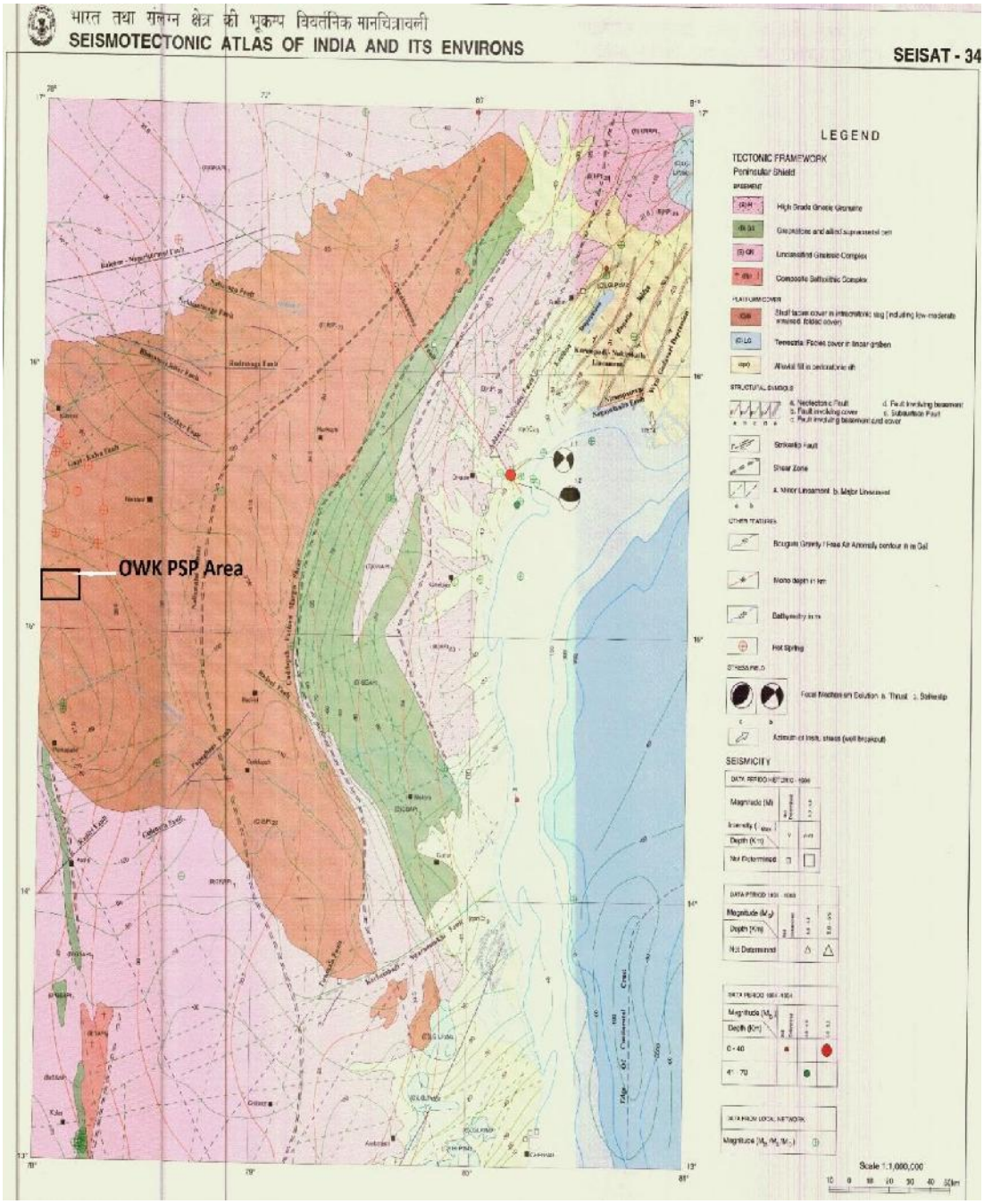


Fig.5. 3. Seismotectonic map showing project area

5.2.2 Geomorphology and Geology of the Project Area

The project area lies in the southwestern part of the Kadapa district of Andhra Pradesh. Different types of landforms like structural hills, pediment-pediplain, plateau etc. are found in and around the project area.

Quartzite belonging to Gandikota Quartzite Formation, shale and tuff of Tedpatri Formation, both under Chitravati Group are present in and around the project site. The general strike of the rocks is N40°W-S40°E and dip 5°-15° towards N50°E.

The proposed project envisages construction of an artificial reservoir in the upper reaches where the water is passing through a HRT-Pressure shaft- penstock to an Underground powerhouse- TRT to the lower reservoir located at the lower reaches. Two alternate proposals of combined bund & pit upper reservoir have been studied by WAPCOS. The option-1 is located 1925.0m NNW of the existing reservoir and option-2 is located 4.3Km southeast of the existing lower reservoir. Option-1 is selected on the basis of techno-economic feasibility study. However, detailed study of all alternative options will also be done at FSR/DPR stage.

The preliminary geological assessment of project components is as presented below.

5.3 Upper Reservoir

A 5460.81m perimeter of a wide pool is to be created by excavation for the artificial reservoir at the upper reaches. The proposed FRL of the upper reservoir will be at EI.490.0m and MDDL is at EI.470.0m. Therefore, a 10.0m deep pit is proposed to be excavated from NSL. El. 480.0m up to El. 470.0m and 23.0m height bund have been proposed upto EI.493.0m which will serve the purpose of upper reservoir.

Hard, competent quartzite having high bearing capacity is the major rock type in this area. The general strike is N41°W-S41°E with dip amount of 5-10° towards N49°E.The majority of rockmass may belongs to Class-II/III category, however class-IV/V type rockmass may also be present at weak/shear zones. Necessary slope protection for reservoir rim stability and competency studies for leakage/seepage along major discontinuity planes has to be required. At the excavated slope benches at certain interval may also be required to avoid slope failure. Stitching of wedges through rock bolts/anchors may also be required to prevent failure of vulnerable wedges. All these studies will be carried out during FSR/DPR stage investigations. The excavated muck may be utilized as coarse aggregate during construction.

5.4 Intake

An 8.43m dia intake has been proposed on the excavated reservoir at upper reaches. On the basis of the design and power generation the intake is placed at EI.452.20m whereas the minimum drawdown level is fixed at EI 470m. This structure has been proposed from the new upper reservoir. Optimum layout requirements have been considered to suit the alignment of the Water Conductor in fixing the alignment

of Power Intake. District Resource Map (1:2,50,000 scale) study reveals that hard, competent quartzite will form the tunnelling media. However, shale may also be present below quartzite. The rockmass belongs to Class-II/III categories whereas Class-IV/V categories rockmass may be present at weak/shear zones.

5.5 Head Race Tunnel & Pressure Shaft

A 353 m long and 8.43 m dia concrete lined Head Race Tunnel (HRT) has been proposed. The maximum cover of HRT will be 32m. Actual support system will be decided after geological investigations and analysis at FSR/DPR stage.

A steel lined pressure shaft of 6.76 m dia and 379 m long is also provided. Two horizontal pressure tunnels have been proposed at the bottom. The length of horizontal pressure tunnel will be about 70 m and 4.80m Dia. In general, rock-bolts and lining will be required as support system. Actual support system will be decided after geological investigations and analysis at FSR/DPR stage.

District Resource Map (1:2,50,000 scale) study reveals that mainly quartzite will be present along the HRT alignment. Dolerite dykes may also be present at some places. A tentative geological L-section has been prepared **(Plate-5.2)**, where it shows the tunnel is passing under a minimum cover of 18.0m and maximum cover of 34.0m. Detailed subsurface exploration will be required to ascertain the rockmass condition. In the tunnel portion, it appears that the rockmass belong to Class-IV/V categories may be present at the tunnel grade. Class-VI rockmass may also be present at certain reaches and at the weak/shear zones. Due to insufficient cover above the HRT steel lined HRT has been adopted to reduce the dia as well as friction loss along HRT. Installation of adequate and timely support system in form of shotcrete, and rock bolts as primary support along with installation of steel ribs at certain reaches and drainage of water away from the face by providing drainage holes prior to face advancement in water charged strata, with simultaneous monitoring rock mass behaviour by aid of geotechnical instrumentation may be required. However, actual support system will be decided after geological investigations at DPR stage.

It appears that quartzite may present along the top half portion of the inclined shaft whereas incompetent shale and tuff along the bottom portion. Along the horizontal pressure shaft/tunnel, incompetent shale and tuff will be present. However, detail investigations will be required to confirm the same.

The detail surface and subsurface geological investigations along the proposed HRT – pressure shaft alignment will be carried out in the FSR/ DPR stage

5.6 Powerhouse & Transformer Cavern

An underground powerhouse (UGPH) of 119m (L) x 22m (W) x 49m (H) and a transformer cavern hall of 100m (L) x 18m (W) x 22.5m (H) have been proposed for this project. The power house will have two Francis type vertical shaft reversible units of 300 MW each. The design head for turbine mode as 278.87m and pumping mode as 278.87 m has been assessed. The transformer cavern would be 100m long, its width and height being 18m and 22.5m respectively. A horizontal unit tail race tunnel is proposed. The length of unit tail race tunnel will be 705m and 8.43m dia. Mainly shales form the tunnelling media. The rockmass belong to Class-III/IV category whereas Class-V/VI category rock mass may be present at weak/shear zones. The strike in the region is N41°W-S41°E with dip amount of 5-10° towards N49°E. The L-axis of powerhouse has been aligned along N67°W-S67°E. Therefore, the L-axis of powerhouse making an angle of 26° with the strike of the foliation. However, the alignment of powerhouse is found to be suitable due to low dip of the foliation. A tentative geological L-section has been prepare**d (Plate-5.2),** where 232.0m cover has been observed. Detail study of stress distribution & deformation by numerical modelling will be required for suitable support measures inside the cavern. Ingress of water along major discontinuities cannot be ruled out. Detailed sub-surface geological investigations will be carried out at FSR/DPR stage for finalization of the orientation of powerhouse, realistic assessment of rock mass condition and to workout actual support system. An exploratory drift will also be required to know the rockmass condition inside the powerhouse. This will be done during FSR/DPR stage investigation

5.7 Trail race Tunnel

A one no. of 8.43m dia and 705m long concrete lined TRT has been proposed. The rock cover along TRT will vary from 45m to 268m. TRT will be provided with suitable rock support system depending upon the geological strata. Relatively competent rock like dolomite, tuff, and less competent shales form the tunneling media. The rockmass belong to Class-III/IV category whereas Class-V/VI category rockmass may be present at weak/shear zones. Ingress of water along major discontinuities cannot be ruled out. The detail study of surface mapping and sub-surface explorations in this will be carried out during FSR/DPR stage. Suitable rock support system depending upon the geological strata. Actual support system will be decided after geological investigations and analysis at FSR/DPR stage

5.8 Construction Material

5.8.1 Coarse aggregate

A number of mafic rocks of volcanic origin are present in and around the project **(Plate-5.2).** Fresh mafic rocks can be used as coarse aggregate of concrete. Again, hard, competent quartzite outcrops are also present in the vicinity of project site which can also be used. However, determination of engineering properties and quantity assessment will be undertaken during FSR/DPR stage to know their suitability for wearing and non-wearing surfaces as well as availability of sufficient quantities

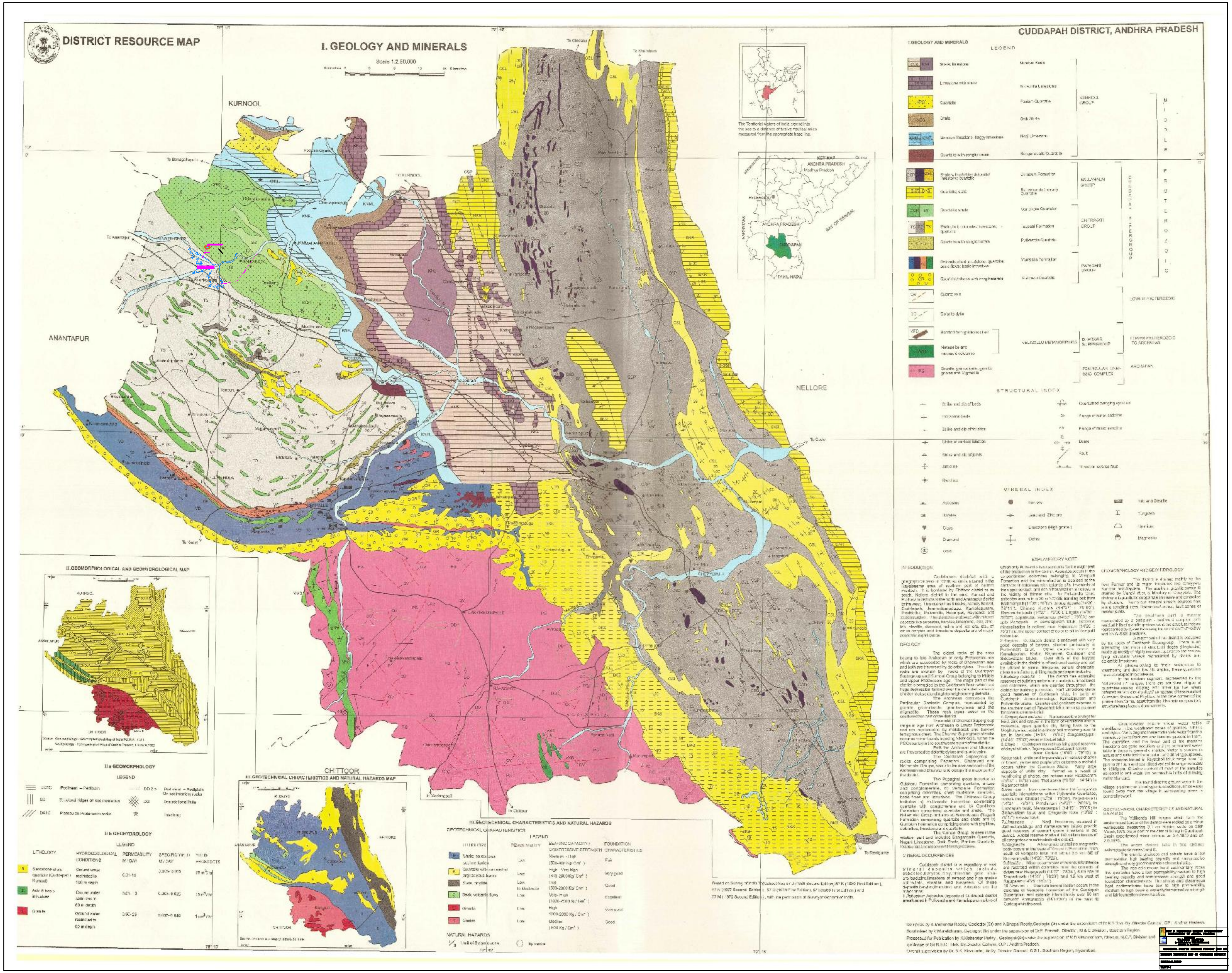
5.8.2 Fine aggregate

The sand deposit of Chitravati River may be utilized as fine aggregates. However, suitable quarry sites will be selected in FSR/DPR stage. The required tests will be done to know their suitability. In addition, the material from crushing of fresh rock (mafic rocks & quartzite) may also be used as fine aggregate, if found suitable.

5.9 Conclusions and Recommendations

The proposed Gandikota Pumped Storage Project envisages utilization of water from an artificial reservoir proposed as upper reservoir, which is constructed by excavating a Pit with Bund type reservoir through an Intake-HRT-penstock-Pressure shaft to an underground powerhouse to generate 600MW of power by utilizing gross head of 269.8m. The option-1 has been chosen depending upon the techno-economic feasibility. Detailed investigations will be required during preparation of FSR/DPR. Prima facie, on the basis of the preliminary geological studies it can be concluded that no geological surprise is envisaged. Geological setup is conducive for underground works. Overall geology of the project area is good and the project has merits for taking up for FSR / DPR stage investigations.

Plate - 5.1


DISTRICT RESOURCE MAP
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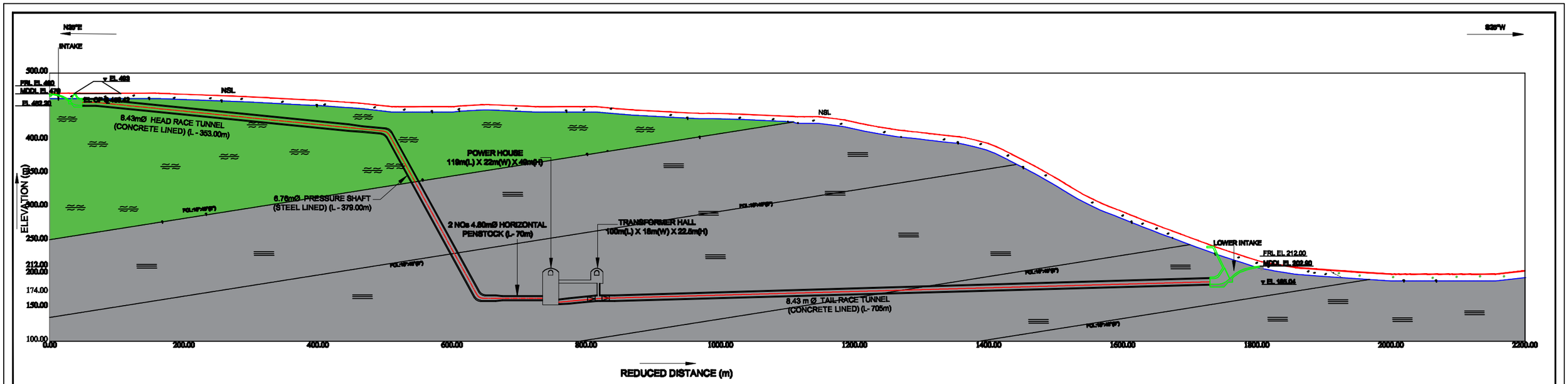
NELLORE
CHITTOOR
LEGEND
STRUCTURAL INDEX
MINERAL INDEX
EXPLANATORY NOTE
II. GEOMORPHOLOGICAL AND GEOHYDROLOGICAL MAP
II a GEOMORPHOLOGY
II b GEOHYDROLOGY
III. GEOTECHNICAL CHARACTERISTICS AND NATURAL HAZARDS MAP

Plate - 5.2



Index

NEW & RENEWABLE ENERGY DEVELOPMENT CORPORATION OF ANDHRA PRADESH

CONSULTANTS
WAPCOS LIMITED
(A GOVERNMENT OF INDIA UNDERTAKING)
MINISTRY OF JAL SHAKTI

GANDIKOTA PUMPED STORAGE PROJECT (600 MW)

GEOLOGICAL L-SECTION OF WATER CONDUCTER SYSTEM

PLATE-II

CHAPTER-6: PROJECT PLANNING & IC

CHAPTER - 6

6. PROJECT PLANNING AND INSTALLED CAPACITY

6.1 Introduction

The existing Gandikota Reservoir project is located near Gandikota Village in Kurnool district, Andhra Pradesh on the river Paleru which is a tributary of the Krishna River. The catchment area calculated at the dam site is 19197 sq. km. The reservoir with gross capacity of 759.6 MCM and Live storage 671.28 MCM.

6.2 Gandikota Pump Storage Project

The proposed pump storage project has been planned by using the existing Gandikota Reservoir as lower reservoir for the Pumped storage scheme with Full Reservoir Level of El. 212m and Minimum draw down level of El. 202.9m. A new upper reservoir of bund Type will be formed. The optimum possible live storage capacity required for the scheme is 4.67 MCM which has been finalised based on the topography and geology of the upper dam. The proposed project will generate 600 MW of power

6.3 Gandikota Reservoir - Upper Reservoir

The upper reservoir of pumped storage operation of the project. The reservoir has a live storage capacity of 4.67 MCM as under.

Table: 6.1

Particulars	Elevation (m)	Storage (million m^3)
FRL	490	5.03
MDDL	470	0.36
Live Storage		**4.67**

6.4 Gandikota Lower Reservoir (Existing)

The following parameters have been considered for existing reservoir and live capacity of lower reservoir will be 671.28 MCM.

Table: 6.2

Particulars	Elevation (m)	Storage (million m^3)
FRL	212	759.6
MDDL	202.9	88.34
Live Storage		671.28

6.5 Operating Gross Head

Gross operating head on the pumped storage units would vary from 267.41m to 286.86m. The minimum gross head is 93.21% of the maximum gross head. The head loss in the water conductor system has been estimated as 6 m. and accordingly, the net design head on the machine would vary from 261.41 m to 280.86 m.

6.6 Installed Capacity

Considering the availability of the diurnal storage capacity in lower reservoir an installation of 600 MW comprising 2 units of 300 MW has been provided. The project would provide peaking capacity of 600 MW for 5 hours' and 5 Minutes block.

6.7 Power Scenario in Andhra Pradesh

The installed generating capacity in Andhra Pradesh as on 30th November 2019 was 24518.36MW comprising as under:

Table: 6.3

Type	**Installed Capacity**	
	(MW)	**(%)**
Thermal	14643.82	59.73%
Hydro	1673.6	6.83%
RES	8073.67	32.94%
Total	**24518.36**	**100%**

The share of hydro in the present installed capacity is about 6.83% which is quite less. Therefore, to ameliorate the situation, development of pumped storage project would need to be considered to meet the growth in the peaking capacity requirement of the power system.

6.8 Operation Simulation

The operation simulation of the two reservoirs for pumped storage operation has been carried out considering the storage characteristics. The simulation has been carried out considering a shorter time interval of 10 minutes to take into account the level variations in the two reservoirs

6.8.1 Lower Reservoir

The storage of lower reservoir is 671.28 MCM and has been considered for pump-storage operation.

6.8.2 Generator Turbine efficiency

The efficiency of the pump-turbine unit during generating mode is adopted as 89% and during the pumping mode is adopted as 91%.

6.8.3 Losses in the Water Conductor System

The losses in the water conductor system have been considered as 6 m.

6.9 Operation Simulation Studies

The studies have been carried out at the beginning of generating cycle, the Upper reservoir is at FRL and Lower reservoir at MDDL.

The simulation studies have been carried out for the initial reservoir levels as under.

Table: 6.4

Reservoir	**Initial Reservoir Level**
Upper reservoir	FRL El. 490 m
Lower reservoir	MDDL El. 202.90 m

The results of the simulation studies for generating mode are given in **Annexure- 6** and summarized below.

- At the beginning of the generation, the Gandikota reservoir is at FRL El. 490 m. The reservoir draws down to El. 470.17 m in 5 hours and 5 minutes of full load operation representing a drawdown of 19.83 m.
- The storage utilized for operation is 4.63 million m^3.

- At the start of generation, the Lower reservoir is at its MDDL 202.90m and a rise of 6.2 cm in the reservoir level.
- The energy generation during the period is 3050 MWh and annually generation of 1113.25GWh of energy.

The simulation studies for pumping mode are given in **Annexure-6**. The pumping energy requirement would be 3810 MWh and annually pumping energy of 1390.65 GWh which gives a cycle efficiency of 80.052%.

6.10 Source of Pumping

The hydro power share in Andhra Pradesh is 6.83% whereas the state depends mainly on thermal power generation. In view of the large capacity in the region, there would be adequate availability of off-peak power for pumping operation

Annexure - 6

Gandikota Pumped Storage Project H.E. Project

Generation Operation Simulation Studies

Operating Levels and Storage available at Reservoirs

Upper reservoir	Level (m)	Storage (MCum)	Lower reservoir	Level (m)
FRL	490.00	5.03	FRL	212.00
MDDL	470.00	0.36	MDDL	202.90
Live Storage		4.67	Live Storage	

Scenario: Operating Levels considered for Operation Simulation

Upper reservoir	Level (m)	Lower reservoir	Level (m)	Storage (MCum)
FRL-PS Operation	490.00	FRL-PS Operation	202.96	-
MDDL-PS Operatio	470.17	MDDL-PS Operation	202.90	-
Pondage for PS Ope	4.63	Pondage for PS Operation		4.63

				Upper Pond				Lower Pond					
Interval No	Time Interval (Minutes)	Station Output (MW)	Discharge (cumecs)	Initial Pond Level (m)	Outflow from Pond (MCum)	Final Pond Level (m)	Average Pond Level (m)	Initial Pond Level (m)	Inflow into Pond (MCum)	Final Pond Level (m)	Average Pond Level (m)	Average Net Head (m)	Energy Generation (MWh)
1	10.0	600.0	244.68	490.00	0.15	489.52	489.76	202.900	0.15	202.902	202.901	280.86	100.00
2	10.0	600.0	245.13	489.52	0.15	488.98	489.25	202.902	0.15	202.904	202.903	280.34	100.00
3	10.0	600.0	245.61	488.98	0.15	488.43	488.70	202.904	0.15	202.906	202.905	279.80	100.00
4	10.0	600.0	246.10	488.43	0.15	487.87	488.15	202.906	0.15	202.908	202.907	279.24	100.00
5	10.0	600.0	246.59	487.87	0.15	487.31	487.59	202.908	0.15	202.910	202.909	278.68	100.00
6	10.0	600.0	247.10	487.31	0.15	486.74	487.03	202.910	0.15	202.912	202.911	278.12	100.00
7	10.0	600.0	247.61	486.74	0.15	486.16	486.45	202.912	0.15	202.914	202.913	277.54	100.00
8	10.0	600.0	248.13	486.16	0.15	485.58	485.87	202.914	0.15	202.916	202.915	276.96	100.00
9	10.0	600.0	248.66	485.58	0.15	484.98	485.28	202.916	0.15	202.918	202.917	276.36	100.00
10	10.0	600.0	249.20	484.98	0.15	484.38	484.68	202.918	0.15	202.920	202.919	275.76	100.00
11	10.0	600.0	249.75	484.38	0.15	483.77	484.08	202.920	0.15	202.922	202.921	275.16	100.00
12	10.0	600.0	250.31	483.77	0.15	483.16	483.46	202.922	0.15	202.924	202.923	274.54	100.00
13	10.0	600.0	250.88	483.16	0.15	482.53	482.84	202.924	0.15	202.926	202.925	273.92	100.00
14	10.0	600.0	251.46	482.53	0.15	481.90	482.21	202.926	0.15	202.928	202.927	273.29	100.00
15	10.0	600.0	252.05	481.90	0.15	481.25	481.57	202.928	0.15	202.930	202.929	272.65	100.00
16	10.0	600.0	252.66	481.25	0.15	480.60	480.93	202.930	0.15	202.932	202.931	272.00	100.00
17	10.0	600.0	253.27	480.60	0.15	479.94	480.27	202.932	0.15	202.934	202.933	271.34	100.00
18	10.0	600.0	253.89	479.94	0.15	479.28	479.61	202.934	0.15	202.936	202.935	270.67	100.00
19	10.0	600.0	254.52	479.28	0.15	478.60	478.94	202.936	0.15	202.939	202.937	270.00	100.00
20	10.0	600.0	255.17	478.60	0.15	477.91	478.26	202.939	0.15	202.941	202.940	269.32	100.00
21	10.0	600.0	255.83	477.91	0.15	477.22	477.57	202.941	0.15	202.943	202.942	268.63	100.00
22	10.0	600.0	256.49	477.22	0.15	476.52	476.87	202.943	0.15	202.945	202.944	267.93	100.00
23	10.0	600.0	257.18	476.52	0.15	475.81	476.16	202.945	0.15	202.947	202.946	267.22	100.00
24	10.0	600.0	257.87	475.81	0.15	475.09	475.45	202.947	0.15	202.949	202.948	266.50	100.00
25	10.0	600.0	258.57	475.09	0.16	474.36	474.72	202.949	0.16	202.951	202.950	265.77	100.00
26	10.0	600.0	259.29	474.36	0.16	473.62	473.99	202.951	0.16	202.953	202.952	265.03	100.00
27	10.0	600.0	260.02	473.62	0.16	472.87	473.24	202.953	0.16	202.955	202.954	264.29	100.00
28	10.0	600.0	260.77	472.87	0.16	472.11	472.49	202.955	0.16	202.957	202.956	263.53	100.00
29	10.0	600.0	261.53	472.11	0.16	471.34	471.73	202.957	0.16	202.960	202.958	262.77	100.00
30	10.0	600.0	262.30	471.34	0.16	470.57	470.96	202.960	0.16	202.962	202.961	261.99	100.00
31	5.0	600.0	262.89	470.57	0.08	470.17	470.37	202.962	0.08	202.963	202.962	261.41	50.00
	305.00				4.63				4.63				3050.00

MCum - Million Cubic Metres

Operation Time (hrs)	5hr 5 min
Head Loss (m)	6.00
Generating mode effficiency	0.89

Gandikota Pumped Storage Project H.E. Project

Pumping Operation Simulation Studies

Operating Levels and Storage available at Reservoirs

Upper reservoir	Level (m)	Storage (MCum)	Lower reservoir	Level (m)
FRL	490.00	5.03	FRL	212.00
MDDL	470.00	0.36	MDDL	202.90
Live Storage		4.67	Live Storage	

Scenario: Operating Levels considered for Operation Simulation

Upper reservoir	Level (m)	Lower reservoir	Level (m)	Storage (MCum)
FRL-PS Operation	470.00	FRL-PS Operation	211.94	-
MDDL-PS Operatic	489.92	MDDL-PS Operation	212.00	-
Pondage for PS Op	4.63	Pondage for PS Operation		4.63

				Upper Pond				Lower Pond					
Interval No	Time Interval (Minutes)	Station Output (MW)	Discharge (cumecs)	Initial Pond Level (m)	Outflow from Pond (MCum)	Final Pond Level (m)	Average Pond Level (m)	Initial Pond Level (m)	Inflow into Pond (MCum)	Final Pond Level (m)	Average Pond Level (m)	Average Net Head (m)	Energy Generation (MWh)
1	10.0	600.0	210.59	470.00	0.13	470.60	470.30	212.000	0.13	211.998	211.999	264.30	100.00
2	10.0	600.0	210.10	470.60	0.13	471.22	470.91	211.998	0.13	211.997	211.997	264.91	100.00
3	10.0	600.0	209.61	471.22	0.13	471.84	471.53	211.997	0.13	211.995	211.996	265.53	100.00
4	10.0	600.0	209.12	471.84	0.13	472.45	472.14	211.995	0.13	211.993	211.994	266.15	100.00
5	10.0	600.0	208.65	472.45	0.13	473.05	472.75	211.993	0.13	211.991	211.992	266.76	100.00
6	10.0	600.0	208.18	473.05	0.12	473.65	473.35	211.991	0.12	211.990	211.991	267.36	100.00
7	10.0	600.0	207.71	473.65	0.12	474.24	473.94	211.990	0.12	211.988	211.989	267.96	100.00
8	10.0	600.0	207.25	474.24	0.12	474.83	474.53	211.988	0.12	211.986	211.987	268.55	100.00
9	10.0	600.0	206.80	474.83	0.12	475.41	475.12	211.986	0.12	211.985	211.986	269.13	100.00
10	10.0	600.0	206.36	475.41	0.12	475.98	475.70	211.985	0.12	211.983	211.984	269.71	100.00
11	10.0	600.0	205.92	475.98	0.12	476.55	476.27	211.983	0.12	211.981	211.982	270.28	100.00
12	10.0	600.0	205.49	476.55	0.12	477.11	476.83	211.981	0.12	211.980	211.981	270.85	100.00
13	10.0	600.0	205.06	477.11	0.12	477.67	477.39	211.980	0.12	211.978	211.979	271.41	100.00
14	10.0	600.0	204.65	477.67	0.12	478.22	477.95	211.978	0.12	211.976	211.977	271.97	100.00
15	10.0	600.0	204.23	478.22	0.12	478.77	478.50	211.976	0.12	211.975	211.976	272.52	100.00
16	10.0	600.0	203.82	478.77	0.12	479.31	479.04	211.975	0.12	211.973	211.974	273.07	100.00
17	10.0	600.0	203.42	479.31	0.12	479.85	479.58	211.973	0.12	211.971	211.972	273.61	100.00
18	10.0	600.0	203.03	479.85	0.12	480.38	480.11	211.971	0.12	211.970	211.971	274.14	100.00
19	10.0	600.0	202.63	480.38	0.12	480.90	480.64	211.970	0.12	211.968	211.969	274.67	100.00
20	10.0	600.0	202.25	480.90	0.12	481.42	481.16	211.968	0.12	211.966	211.967	275.19	100.00
21	10.0	600.0	201.87	481.42	0.12	481.93	481.68	211.966	0.12	211.965	211.966	275.71	100.00
22	10.0	600.0	201.49	481.93	0.12	482.44	482.19	211.965	0.12	211.963	211.964	276.22	100.00
23	10.0	600.0	201.13	482.44	0.12	482.94	482.69	211.963	0.12	211.962	211.962	276.73	100.00
24	10.0	600.0	200.76	482.94	0.12	483.44	483.19	211.962	0.12	211.960	211.961	277.23	100.00
25	10.0	600.0	200.40	483.44	0.12	483.93	483.69	211.960	0.12	211.958	211.959	277.73	100.00
26	10.0	600.0	200.05	483.93	0.12	484.42	484.18	211.958	0.12	211.957	211.957	278.22	100.00
27	10.0	600.0	199.70	484.42	0.12	484.90	484.66	211.957	0.12	211.955	211.956	278.71	100.00
28	10.0	600.0	199.35	484.90	0.12	485.38	485.14	211.955	0.12	211.953	211.954	279.19	100.00
29	10.0	600.0	199.02	485.38	0.12	485.85	485.62	211.953	0.12	211.952	211.953	279.66	100.00
30	10.0	600.0	198.68	485.85	0.12	486.32	486.09	211.952	0.12	211.950	211.951	280.14	100.00
31	10.0	600.0	198.35	486.32	0.12	486.78	486.55	211.950	0.12	211.949	211.949	280.60	100.00
32	10.0	600.0	198.02	486.78	0.12	487.24	487.01	211.949	0.12	211.947	211.948	281.06	100.00
33	10.0	600.0	197.70	487.24	0.12	487.69	487.47	211.947	0.12	211.945	211.946	281.52	100.00
34	10.0	600.0	197.39	487.69	0.12	488.14	487.92	211.945	0.12	211.944	211.945	281.97	100.00
35	10.0	600.0	197.08	488.14	0.12	488.58	488.36	211.944	0.12	211.942	211.943	282.42	100.00
36	10.0	600.0	196.77	488.58	0.12	489.02	488.80	211.942	0.12	211.941	211.941	282.86	100.00
37	10.0	600.0	196.46	489.02	0.12	489.45	489.24	211.941	0.12	211.939	211.940	283.30	100.00
38	10.0	600.0	196.17	489.45	0.12	489.88	489.67	211.939	0.12	211.937	211.938	283.73	100.00
39	1.0	600.0	196.00	489.88	0.01	489.92	489.90	211.937	0.01	211.937	211.937	283.96	10.00
	381.00				4.63				4.63				3810.00

MCum - Million Cubic Metres

Operation Time (hrs)	6 hr 21 min.	Cycle efficiency	80.052 %
Head Loss (m)	6.00		
Pumping mode effficiency	0.91		

CHAPTER-7: DESIGN OF CIVIL STRUCTURES

CHAPTER – 7

7. PLANNING & DESIGN OF CIVIL STRUCTURES

7.1 The Scheme

The Gandikota Reservoir project is located near Kondapuram Village in Kadapa district, Andhra Pradesh on the Pennar River. The purpose of this project is an irrigation and Kadapa district is benefitted.

The catchment area at the dam site is 19197 sq. km. The reservoir is having Gross storage of 26.84 TMC (759.6 MCM) and Dead storage 3.12 TMC (88.34 MCM). The total length is 320.00m and the max. Flood discharge is 8,180 Cumec.

It is envisaged to utilise the existing Gandikota Reservoir as Lower pond for the proposed PSP scheme by locating upper pond at a suitable higher location in the vicinity The Geographical coordinate of Gandikota Lower reservoir is at Lat. N 14° 48' 28.54'' and Long. E 78° 15' 5.41'' and Upper Reservoir is Lat. N 14° 49' 47.28'' and Long. E 78° 13' 53.23''

7.2 Present Proposal

Accordingly, the existing Gandikota Reservoir has been proposed as lower reservoir for the Pumped storage scheme with Full Reservoir Level of 212m and Minimum draw down level of 202.90m. An artificial Reservoir is proposed as upper Reservoir which is constructed by composite bund & excavating Pit Type Reservoir at Elevation-470.0m. The live storage capacity for pump storage scheme required is only 4.67 MCM. The proposed project will generate 600 MW of power by utilizing net design head of 269.87m. The water from the upper reservoir will be diverted through Power House and TRT to the lower reservoir. The water will be pumped back to the upper reservoir through TRT-Reversible Turbines-pressure shaft-HRT to upper reservoir

7.3 Selection of Layout - General

The concept of pumped storage Projects are broadly categorized in two types as under: -

- Closed-loop pumped storage projects are not continuously connected to a naturally-flowing water feature.

- Open-loop pumped storage projects are continuously connected to a naturally-flowing water feature.

In Closed loop systems, the upper reservoir or Lower reservoir or both reservoirs have little or no natural drainage catchment basin. The upper basin is generally filled using water pumped from the lower reservoir. Closed loop systems are often preferred because of the fewer environmental impacts associated with these types of developments.

A water source nearby helps in providing the initial water required as well as replenish any water losses. Potential off-stream water sources can include groundwater, sea water, and treated wastewater. The upper basin may also fill using water pumped from the lower reservoir, if natural flow is not available.

The Proposed scheme is categorized as open loop Pump Storage type. The Lower reservoir is an existing reservoir namely Gandikota Reservoir which is connected to natural stream. The Upper reservoir is proposed as an artificial reservoir at higher elevation to gain the available head. Based on the preliminary study of the topography of the area, there are two locations for upper reservoirs which have been identified at this stage. However, it is proposed that a detailed study will be required during FSR/DPR stage to further examine with extensive investigation and data with regard to topography and geology etc

Generally following key aspects make any PSP attractive from techno economic standpoint:

1. Topographical features: - If the topography offers high head makes scheme more viable with less cost.

2.Installed Capacity: It is a generally considered that higher installed capacity enhances overall economy of pumped storage project. PSP with installed capacity less than 200 MW is generally not considered very economical.

3. Design Head: it is one of the most important criteria for selection of PSP for the following reasons:

- Higher head results in lesser civil works like smaller height of dams, smaller size of water conductor system and smaller power house complex.
- Higher head results in smaller electro-mechanical components like smaller size of turbine, smaller size of stator and other associated E&M components.
- Higher head require lesser pondage thus results in smaller reservoirs.

- It reduces overall requirement of land for various components of project like size of HRT, TRT etc. together with reduction in quarry/borrow and dumping land requirements.
- However, very little technical know-how is available in the world for handling a project having head more than 800m. Therefore, range of head between 150m to 700m is preferable.

4. L/H Ratio: This aspect is very important in the evaluation of any PSP. Lesser L/H ration has inherent multiple advantages. It generally results in low initial capital cost, less head losses in WCS, reduction or absence of costly surge requirements and better performance of E&M components.

Generally, for heads in the range of 150m to 250m the L/H ration may be of the order of 4 to 6. For higher heads more than 250m to 450m it can be 6 to 10. For heads more than 450m to 700m it can be up to 10 to 14.

5. Geological/geotechnical Setup: A good geological setup enables construction of underground structures as well as for surface structures safely with less cost.

6. Transmission Networks: Easy access to electrical transmission networks and low-cost power for pumping also supports the PSP schemes significantly.

7. **Existing Reservoirs:** Use of an existing reservoir one or both greatly supports in reduction of the project cost with associated mitigation of adverse impact on environment.

7.4 Alternative Layout studies

Since the lower reservoir is existing in the present scheme various alternatives were examined to locate the upper reservoir and two possible options were identified at the nearby hilltop. Technically there are two possible methods to create an artificial upper reservoir either by constructing a bund of requisite height around the flat area available to create pondage for the required generation or excavating a pit to certain depth to create pondage.

The Topography of the project area suggests that, highest contour available in the vicinity of the project is of the order of 470m and 505m. Accordingly two possible location of the Upper Reservoirs namely Option-1 and Option-2 have been considered for optimizing the project layout. The detailed comparison between both the options is stated as under:

Option – 1

In this option, the upper reservoir is proposed on left bank at geographical co-ordinate N- 14˚ 49' 47.78'' and E- 78˚ 13' 53.81'' in NE direction of existing lower Reservoir. The highest possible elevation is at EL-470m on the hilltop. At this location the flat surface area is inadequate to create required capacity in reservoir. Therefore, it is proposed to create pondage through composite bund and pit type upto desired depth for optimum live storage. The length of water conductor is 1567m starting from upper Intake to lower intake. The General Layout Map for Option-I is presented below:

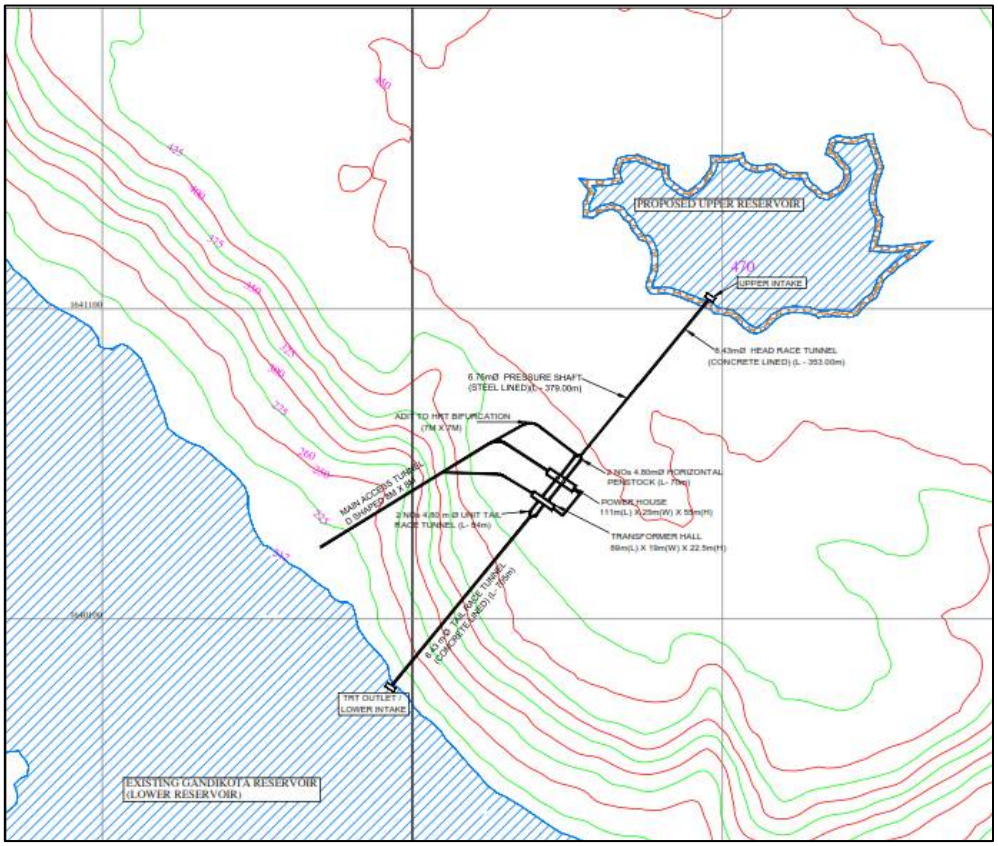


Fig. 7.1 General Layout Map- Option-1

The viability of the project has some technical aspects which have already been elaborated above. The head available in this type of reservoir is 274.36m and similarly live storage is 4.67 MCM.

Option – 2

In this option, the upper reservoir is proposed on right bank at geographical co-ordinate N- 14° 46' 28.93" E- 78° 17' 6.77". The highest possible elevation is at EL-505m on the hilltop. At this location the flat surface area is inadequate to create required capacity in reservoir. Therefore, it is proposed to create

pondage through composite bund and pit type upto desired depth for optimum live storage. The length of water conductor is 2812m starting from upper Intake to lower intake. The General Layout Map for Option-2 is presented below:

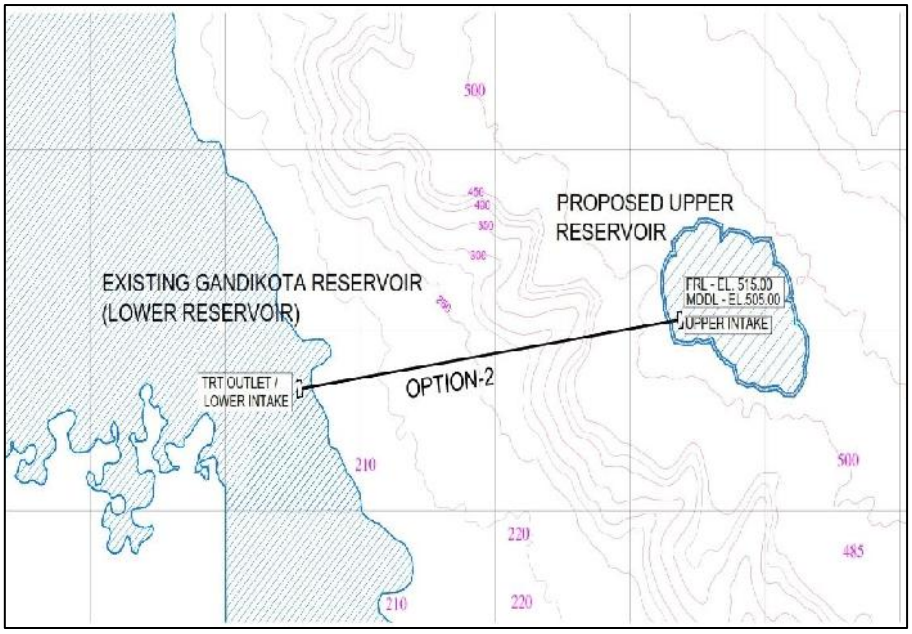


Fig. 7.2 General Layout Map- Option-2

A comparative preliminary analysis is presented below:

Gandikota PSP			
Basic Data		**Basic Data**	
Lower Reservoir (Existing)		**Lower Reservoir (Existing)**	
FRL	212	FRL(m)	212
MDDL	202.9	MDDL(m)	202.9
Upper Reservoir (Option-1)		**Upper Reservoir (Option-2)**	
Reservoir Type – Bund & Pit Combined		**Reservoir Type – Bund & Pit Combined**	
FRL	490	FRL(m)	515
MDDL	470	MDDL(m)	505
Head(m)	274.36	Head(m)	302.55
Length(m)	1567	Length(m)	2812
L/H Ratio	5.71	L/H Ratio	9.29

As evident from above, L/H ratio in option-1 is much less than Option-2 which is a major criterion from techno economic standpoint. Moreover, the Gandikota Village and Wind mill are situated near proposed upper reservoir. Private Land acquisition will impose additional cost and may involve R&R issues. Therefore, Option-1 is more economical and is the preferred option and hence selected at this stage. However, detailed study of all identified alternative options may be taken up at FSR/DPR stage.

An exhibit showing locations of two options is at **Annexure--7.1**. The actual excavation quantity and nature of slope stabilization measures will depend upon the depth of bed rock and can be firmly assessed after carrying out sub surface explorations through drill holes and other associated investigations. The General Layout plan of the selected option i.e. Option-1 is shown in **Annexure--7.2.** The L-Section of the Upper Reservoir is presented in **Annexure--7.3**

7.5 Required live storage/Duration of Generation (hour)

The variation in live storage requirement of reservoir according to different installed capacities are calculated. The same are tabulated below:

IC-550MW				IC-600MW		
Required Live storage/Duration of Generation(hour)				Required Live storage/Duration of Generation(hour)		
4	3.31	MCM		4	3.611	MCM
4.5	3.724	MCM		4.5	4.062	MCM
5	4.137	MCM		5	4.513	MCM
5.5	4.551	MCM		5.5	4.965	MCM
6	4.965	MCM		6	5.416	MCM
Available Live storage in Upper	4.67	MCM		Available Live storage in Upper	4.67	MCM
IC-450MW				IC-500MW		
Required Live storage/Duration of Generation(hour)				Required Live storage/Duration of Generation(hour)		
4	2.708	MCM		4	3.009	MCM
4.5	3.047	MCM		4.5	3.385	MCM
5	3.385	MCM		5	3.761	MCM
5.5	3.724	MCM		5.5	4.137	MCM
6	4.062	MCM		6	4.513	MCM
Available Live storage in Upper	4.67	MCM		Available Live storage in Upper	4.67	MCM

From the above studied different installed capacities, 600MW for 5-hour generation is proposed. The live storage required for this type is 4.67 MCM. However, detailed installed capacity study may be done at DPR stage

7.6 Upper Reservoir/ Bund Type

An artificial upper reservoir having a bund of 5460.81m perimeter and 23m depth is proposed at upper reaches, where the FRL is El.-490m and MDDL is El. 470.0m and an earthen dam of 23m height upto EL-493m.

7.7 Power Intake (Upper & Lower)

Upper Intake structure has been proposed from the new upper reservoir. Optimum layout requirements have been considered to suit the alignment of the Water Conductor in fixing the alignment of Power Intake. The narrow shape of reservoir and low depth in this area complicates the design of the structures. Due to theses constraints the upper intake is proposed to be oriented approximately along the longitudinal axis of the reservoir so that the excavation of Upper reservoir can be reduced and the same has been provided for existing lower reservoir based on the submergence criteria. The detailed design of intake may be done at FSR/DPR stage. Based on these parameters, minimum submergence required has been calculated as per BIS codal practice and Gorden formula for symmetric flow. The L- Section of Upper Intake Structure and Lower Intake structure is shown in **Annexure--7.4.**

7.8 Water Conductor System

Alignment and profile of the waterway is also one of major elements to be optimized in the selection of optimum general layout, because it governs other layouts of structures such as switchyard, access tunnel etc.

Following aspects are considered while finalising the alignment of the waterway from the intake to the tailrace outlet;

- Shortest possible Length of waterway.
- Bends are to be avoided as far as possible.
- Both intake and tailrace outlet are to be aligned in such a way that pumping and generation mode have favorable flow characteristics.

- The rock cover on the powerhouse cavern has been kept more than twice of height of the cavern for proper stability of the cavern.

The Longitudinal section along the alignment of the waterway from the intake to the tailrace outlet/Lower Intake is shown in **Annexure--7.5**. The locations of power intake and tailrace outlet/Lower Intake are selected in the area where stable topographical and geological conditions are seen.

7.9 Head Race Tunnel (Concrete Lined) cum Pressure Shaft (Steel Lined)

One no. of 353 m long and 8.43 m dia Head Race Tunnel (HRT) has been proposed.. The maximum cover of HRT is about 32m. Actual support system will be decided after geological investigations and analysis at FSR/DPR stage. A steel lined pressure shaft of 6.76 m dia and 379 m long is also provided.

Two horizontal pressure tunnels have been proposed at the bottom. The length of horizontal pressure tunnel will be about 70 m and 4.80m Dia. In general, rock-bolts and lining will be required as support system. Actual support system will be decided after geological investigations and analysis at FSR/DPR stage.

7.10 Underground Power house Cavern and Underground Transformer Cavern

An underground Power House (UGPH) of size 119m (L) x 22m (W) x 49m (H) for Option-1 and a transformer cavern hall of 100m (L) x 18m (W) x 22.5m (H) have been proposed for this project. The power house will have two Francis type vertical shaft reversible units of 300 MW each. The design head for turbine mode as 269.87 m and pumping mode as 278.87 m has been assessed. One horizontal unit tail race tunnel are proposed. The length of unit tail race tunnel will be 705m and 8.43m dia. The X-section of power house is shown in **Annexure-7.6**

7.11 Machine Cavern

The machine hall cavern would be 119m in length, 22m in width and overall height of the power house cavity from the lowest excavation of the turbine pit would be 49m. The entrance to the Machine hall cavern shall be through Main Access Tunnel (MAT) of D-Shaped having size 8m x 8m. The auxiliary rooms shall be located at different floors provided on the services bay side of the machine hall cavern.

The penstock for each generating unit would enter the power house horizontally making an angle with the power house longitudinal direction and accommodate the main inlet valve in the machine hall. The

penstock for each unit will terminate into a distributor feeding the turbine nozzles. The center line of the horizontal penstocks entering the power house cavity would be El. 160m in line with nozzles of the turbines.

RCC columns are proposed for supporting the EOT crane beam. A clearance of about 500mm has been provided between the column edge and excavated rock surface to take care of the convergence of power house walls.

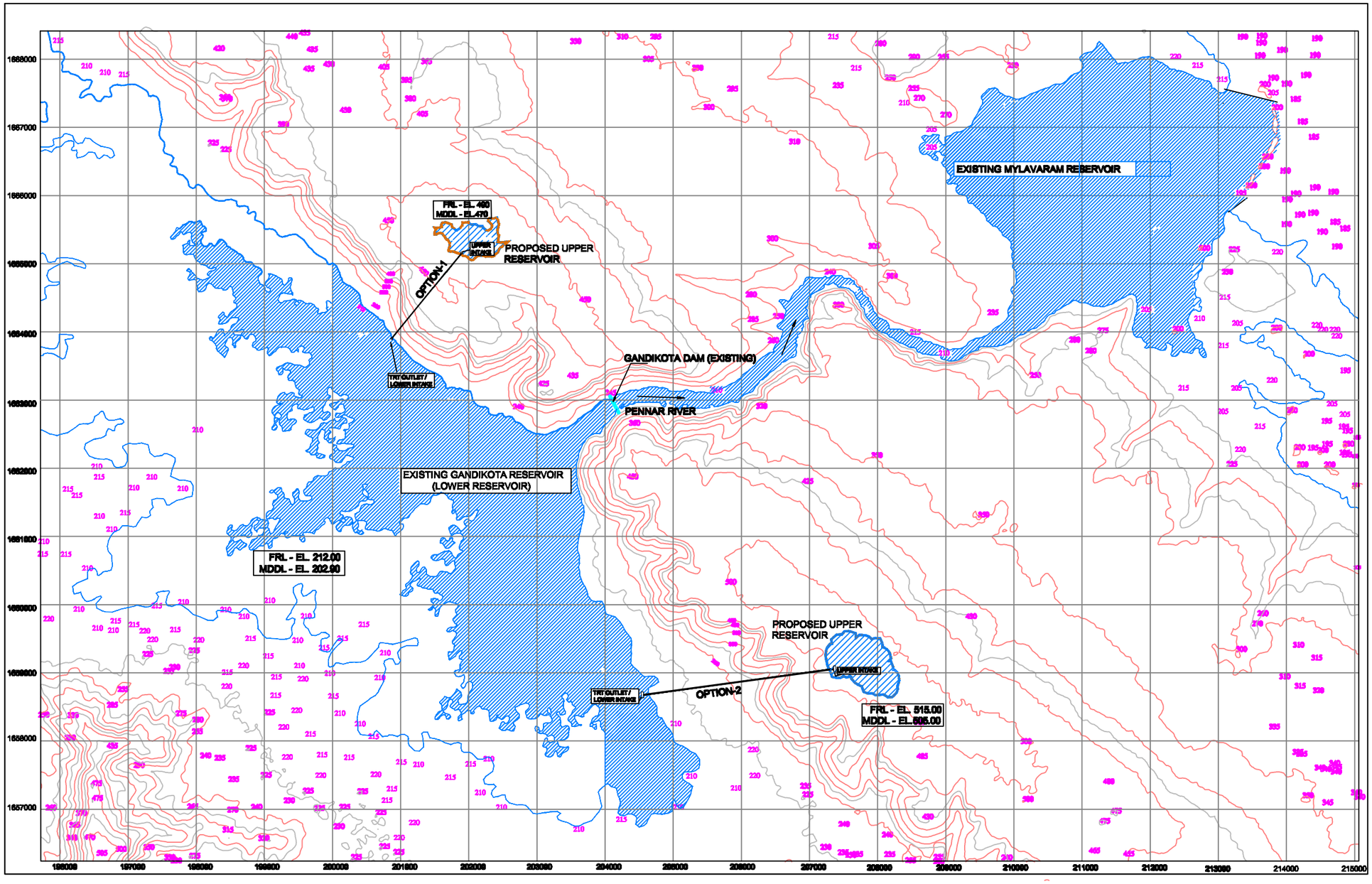
7.12 Transformer cavern

The transformer cavern would be 100m long, its width and height being 18m and 22.5m respectively. It accommodates 2 sets of unit transformers at El. 173m. The roof arch of this cavity would be of circular arch shape with 5.0m rise of crown from the spring level. As in the machine hall cavity, the roof and walls of the transformer cavity are also supported by systematic rock bolting and shotcreting (SFRS), where the rock mass is of poor quality ('Q' value from 1.0 to 2.0), the roof is supported with the combination of shotcrete (SFRS), rock bolts and steel ribs. Provision of drainage holes in regular way has also been made for roof and walls for draining the seepage water adjoining the cavern.

7.13 Tail Race Tunnel (Concrete Lined)

One no. of 8.43m dia and 705m long concrete lined TRT has been proposed.TRT will be provided with suitable rock support system depending upon the geological strata. Actual support system will be decided after geological investigations and analysis at FSR/DPR stage.

Annexure - 7.1



N
W
E
S

MYLAVARAM RESERVOIR

FRL	EI 201.65 m
DSL	EI 199.00 m
LATITUDE	14°50'58.25"
LONGITUDE	78°20'27.35"

GANDIKOTA RESERVOIR (LOWER RESERVOIR)

FRL	EI 212.00 m
DSL	EL 202.9 m
LATITUDE	14 ° 48' 36"
LONGITUDE	78° 15' 30"

PROPOSED UPPER RESERVOIR

FRL	EI 460 m
MDDL	E: 470 m
LATITUDE	14°49'47.25"
LONGITUDE	78°13'53.23"

LEGEND:-

Contour Line Major

Contour Line Minor

Contour Line Intermediate

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WAPCOS LIMITED
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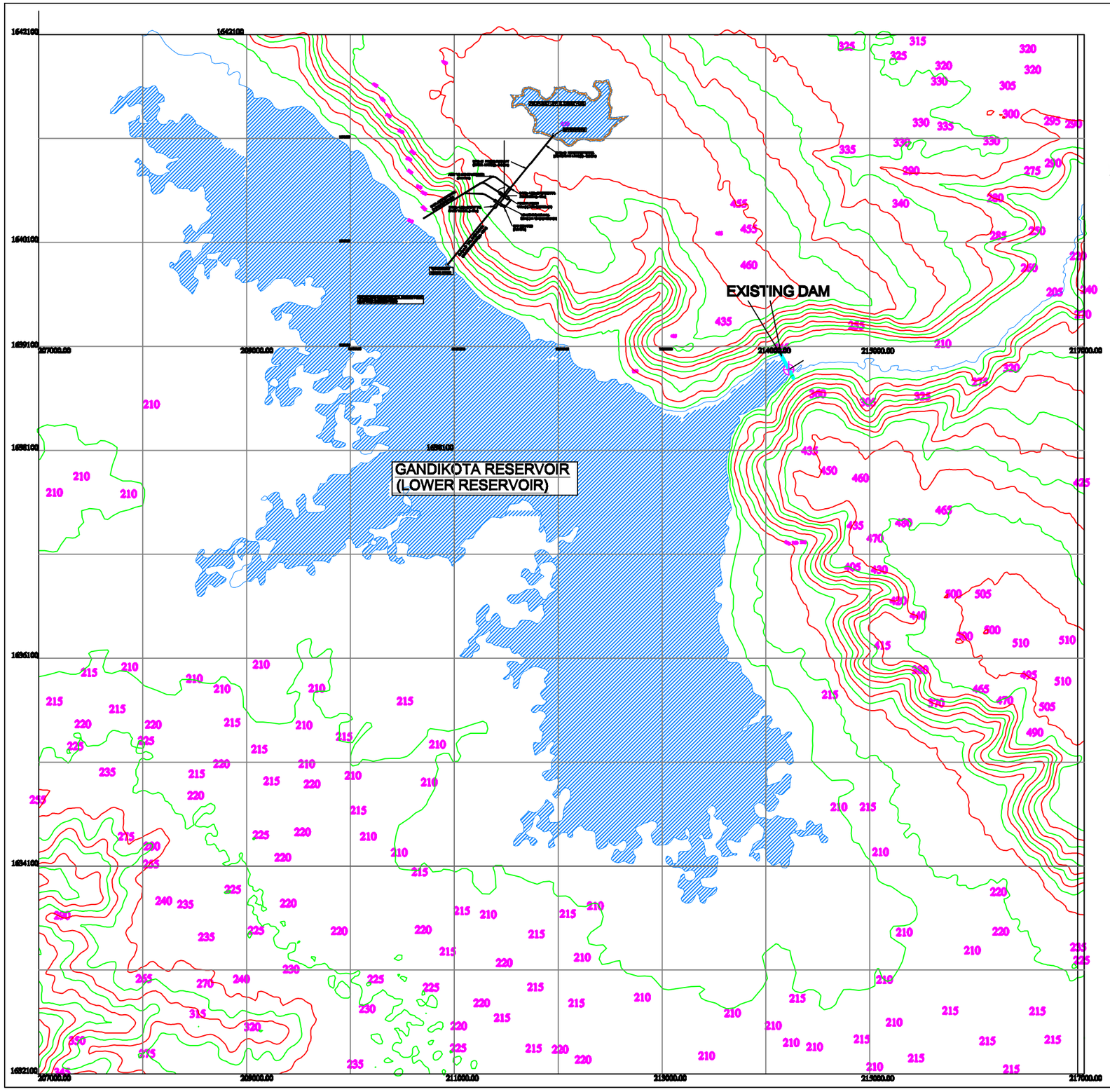
MINISTRY OF JAL SHAKTI

GANDIKOTA PUMPED STORAGE PROJECT (600 MW)

ALTERNATE LAYOUT PLAN

SURVD.	DRAWN	CHKD.
SCALE	REV. NO.	APPRD.
DATE:.....2020		

Annexure - 7.2



GANDIKOTA RESERVOIR (LOWER RESERVOIR)

FRL	212.00 M
DSL	202.90 M
LATITUDE	14 ° 48' 38"
LONGITUDE	78° 15' 30"

PROPOSED UPPER RESERVOIR

FRL	El 490.00
MDDL	El 470.00
LATITUDE	14°49'47.28"
LONGITUDE	78°13'53.23"

LEGEND:-

Contour Line Major

Contour Line Minor

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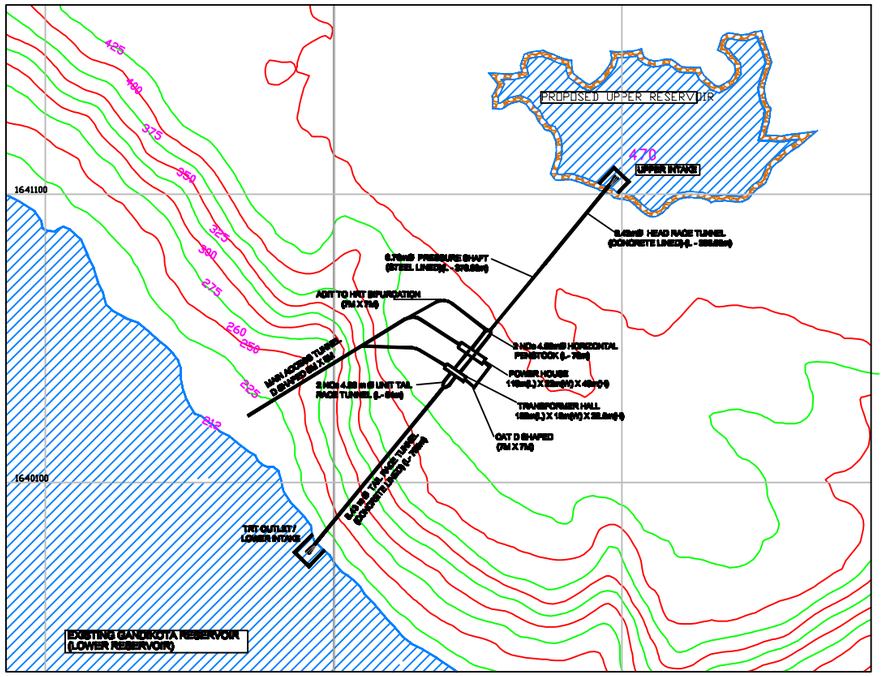
MINISTRY OF JAL SHAKTI

GANDIKOTA PUMPED STORAGE PROJECT (600 MW)

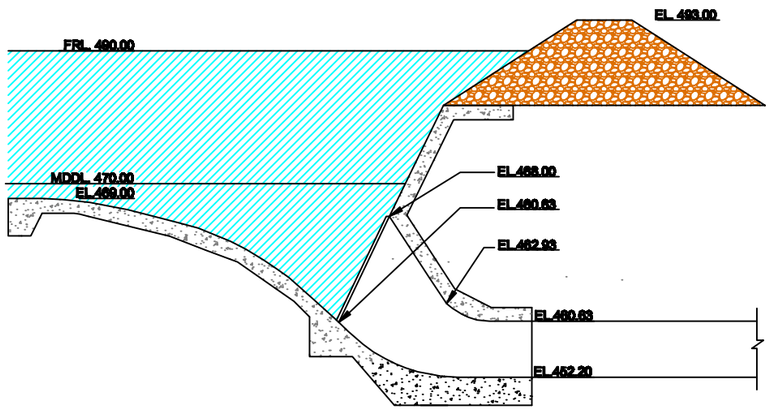
GENERAL LAYOUT PLAN

SURVD.	DRAWN	CHKD.
SUBM.	REV. NO.	APPRD.
DATE:.....-2019		

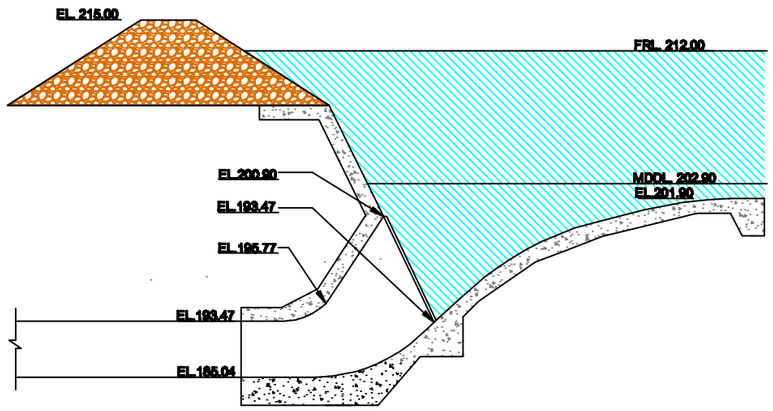
Annexure - 7.3



KEY PLAN



TYPICAL INTAKE IN UPPER RESERVOIR



TYPICAL INTAKE IN LOWER RESERVOIR

PFR STAGE DRAWING

NOTES:-

1. ALL DIMENSIONS ARE IN METER AND ELEVATION IN METER UNLESS AND OTHERWISE SPECIFIED.
2. NO DIMENSION SHALL BE MEASURED FROM THE DRAWING. ONLY WRITTEN DIMENSION SHALL BE FOLLOWED.

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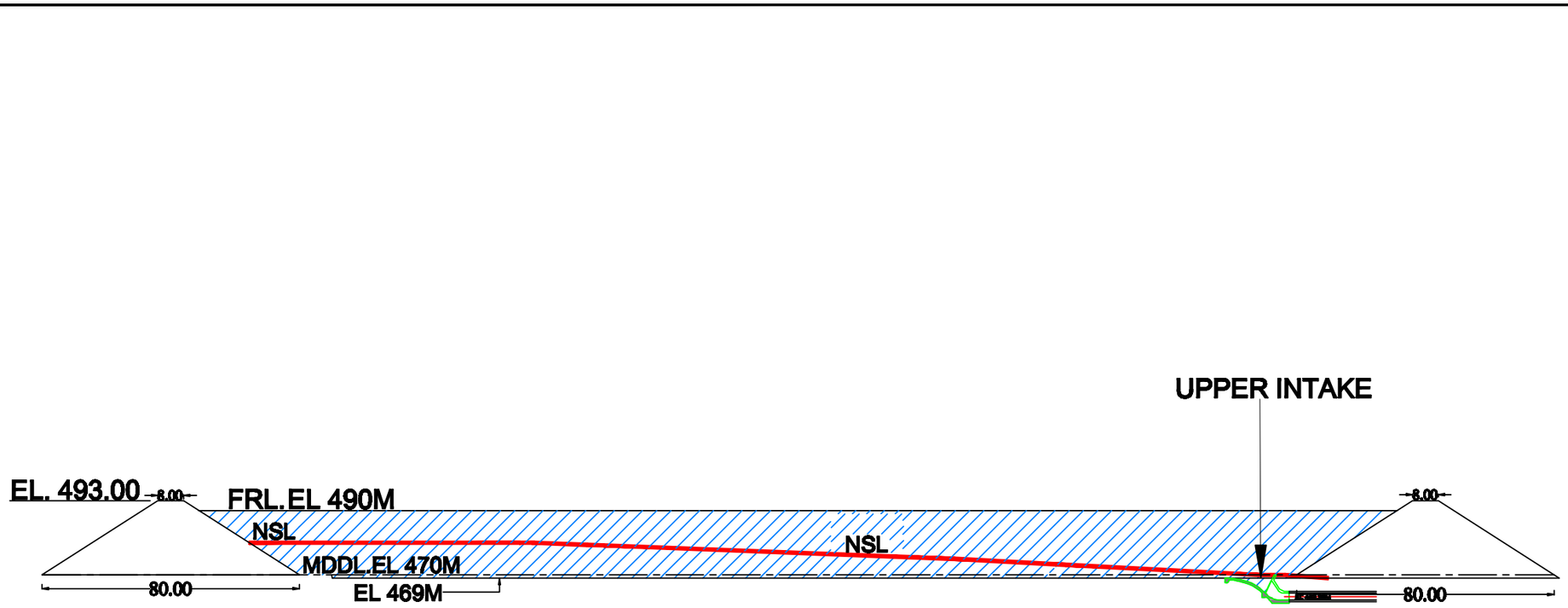
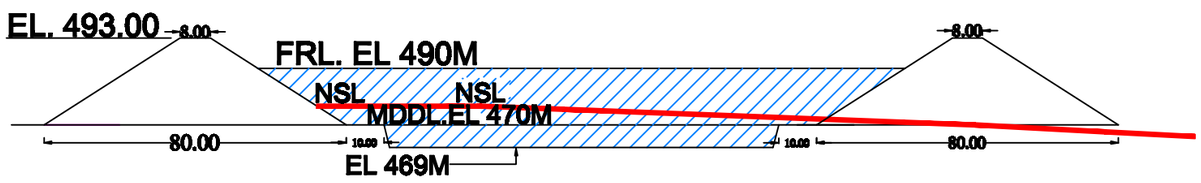
UPPER & LOWER INTAKE

SURVD.	DRAWN	CHKD.
SUBM.	REV. NO.	APPRD.
DATE: FEB-2020		

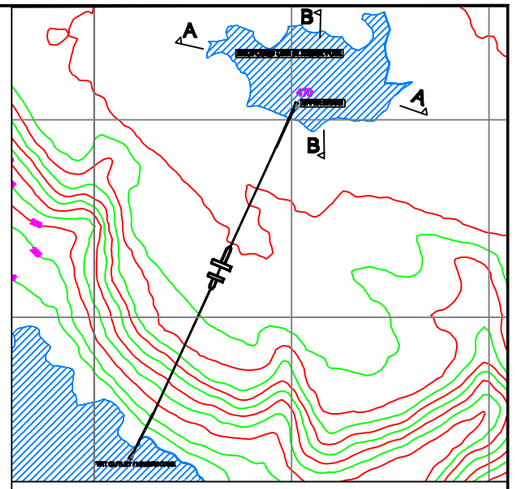
Annexure - 7.4



SECTION A-A



SECTION B-B



KEY PLAN

PFR STAGE DRAWING

NOTES:-

1. ALL DIMENSIONS ARE IN METER AND ELEVATION IN METER UNLESS AND OTHERWISE SPECIFIED.
2. NO DIMENSION SHALL BE MEASURED FROM THE DRAWING.ONLY WRITTEN DIMENSION SHALL BE FOLLOWED.

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GANDIKOTA PUMPED STORAGE PROJECT (600 MW)

L-SECTION & X - SECTION OF UPPER RESERVIOR

SURVD.	DRAWN	CHKD.
SUBM.	REV. NO.	APPRD.
DATE: FEB-2020		

Annexure - 7.5

PFR STAGE DRAWING

UPPER INTAKE

FRL EL 490
MDDL EL 470
EL 482.20

EL 493

EL OF Ø 486.42

NSL

8.43mØ HEAD RACE TUNNEL
(CONCRETE LINED) (L - 353.00m)

A

A

B

B

6.76mØ PRESSURE SHAFT
(STEEL LINED) (L - 379.00m)

POWER HOUSE
119m(L) X 22m(W) X 49m(H)

2 NOs 4.80mØ HORIZONTAL
PENSTOCK (L- 70m)

TRANSFORMER HALL
100m(L) X 18m(W) X 22.5m(H)

C

C

D

D

8.43 m Ø TAIL RACE TUNNEL
(CONCRETE LINED) (L- 705m)

NSL

LOWER INTAKE

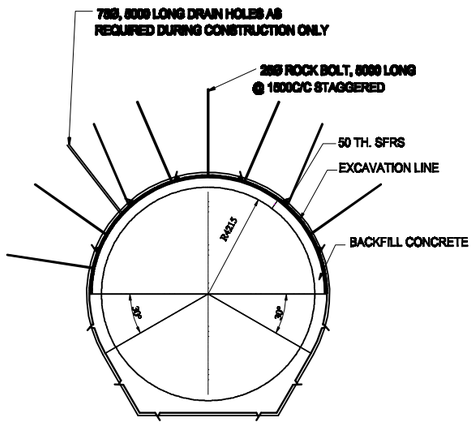
FRL EL 212.00
MDDL EL 202.90

EL 185.04

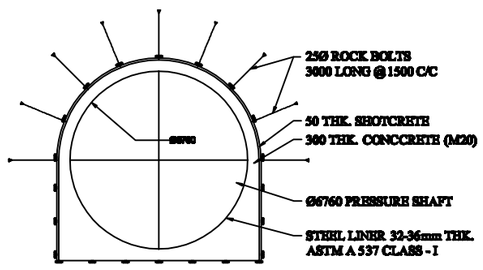
L - SECTION OF PROJECT LAYOUT

NOTES:-

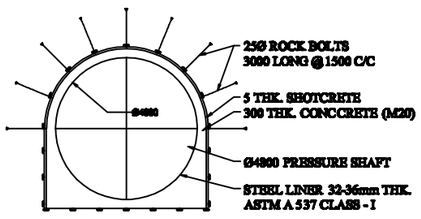
1. ALL DIMENSIONS ARE IN METER AND ELEVATION IN METER UNLESS AND OTHERWISE SPECIFIED.
2. NO DIMENSION SHALL BE MEASURED FROM THE DRAWING.ONLY WRITTEN DIMENSION SHALL BE FOLLOWED.



SECTION AA & DD



SECTION B-B



SECTION C-C

NEW & RENEWABLE ENERGY DEVELOPMENT CORPORATION OF ANDHRA PRADESH

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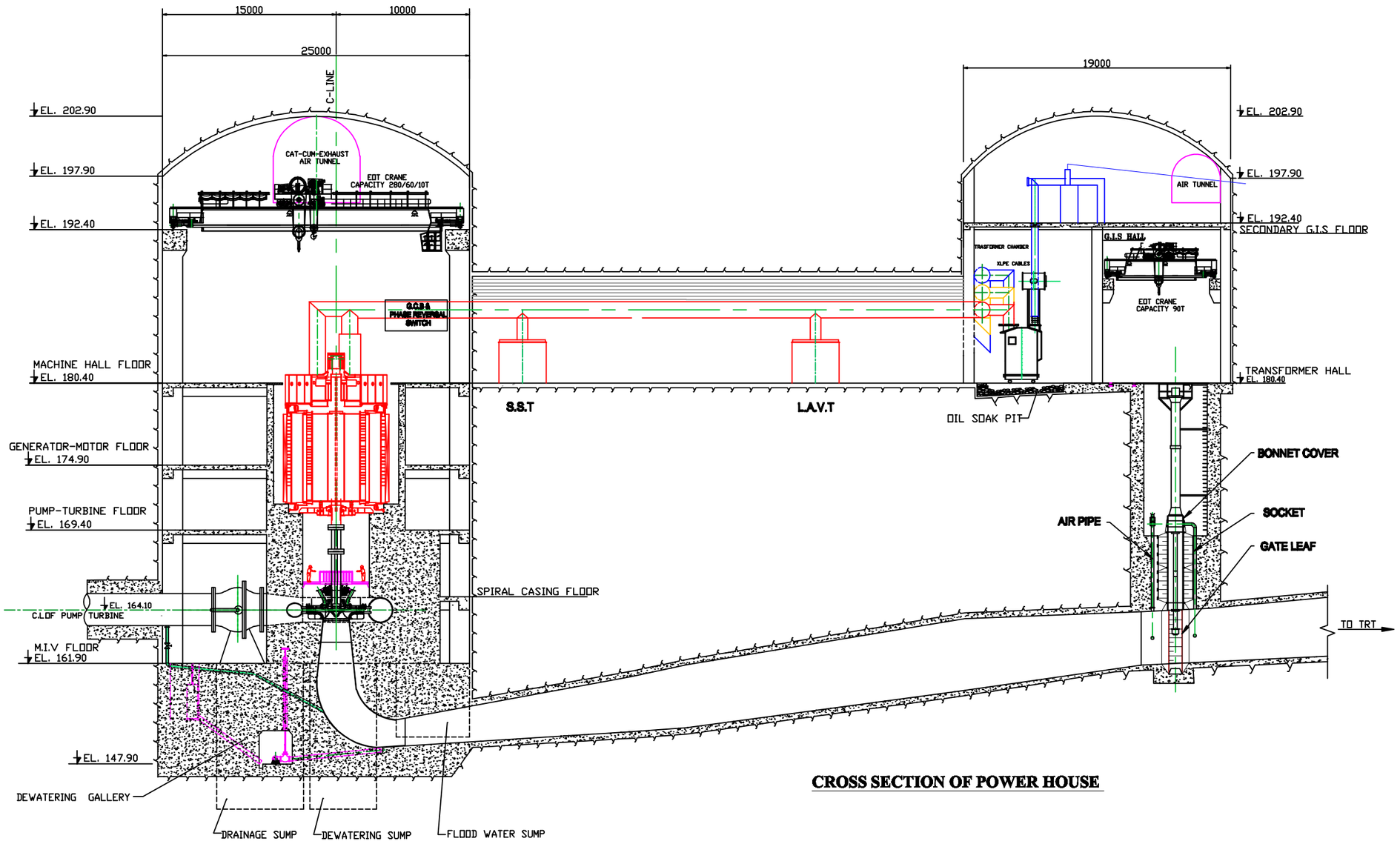
MINISTRY OF JAL SHAKTI

GANDIKOTA PUMPED STORAGE PROJECT (600 MW)

L-SECTION OF PROJECT SITE & CROSS SECTIONS OF CONDUCTOR SYSTEM

SURVD.	DRAWN	CHKD.
SUBM.	REV. NO.	APPRD.
DATE:- FEB-2020		

Annexure - 7.6



CROSS SECTION OF POWER HOUSE

NOTES:-

1. ALL DIMENSIONS ARE IN MILLIMETERS AND ELEVATIOMS IN METERS.
2. THIS IS PFR STAGE DRAWING. THE SAME WILL BE UPDATED DURING DPR.

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CONSULTANTS

WAPCOS LIMITED
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GANDIKOTA PUMPED STORAGE PROJECT (600 MW)

CROSS SECTION OF POWER HOUSE

DEGN.- B.N.SARKAR	CHKD.- B.N.SARKAR	SUBM.-
DRAWN- R.DEY	REV.NO.-	APPD.-
DATE- FEB, 2020	DRG.NO.- WAP/D&RE/AP/ GANDIKOTA /E&M/01	

CHAPTER-8: DESIGN OF E&M EQUIPMENT'S

CHAPTER – 8

8. DESIGN OF ELECTRO-MECHANICAL EQUIPMENT'S

8.1 General

The pumped storage scheme consists of an upper and lower reservoir connected with a water conductor system through an underground power house complex equipped with desired numbers of Generator-Motor and Pump-Turbine units. The Underground power house of Gandikota Pumped Storage scheme will have Two (02) nos. Pump-Turbine units of 300 MW each along with all the auxiliary system such as cooling water system, compressed air system, potable water supply system, fire protection system, ventilation and air conditioning system, illumination system, HT&LT AC and DC systems etc.

8.2 Power House

The entrance to the Machine hall cavern will be through Main Access Tunnel (MAT). The Main Transformer hall cavern will be placed on the downstream of main power house cavern.

The approximate size of the machine hall cavern at EL 173.00 m will be 119 m length (including service bay and control block), 22 m width and 49 m height.

The auxiliary rooms shall be located at different floors with the main control room / block placed on the Unit – 1 side of the machine hall cavern. Control room, Model / Conference room, Engineers room, room for 220 V DC system, HVAC equipment, mechanical workshop etc. shall be located in these auxiliary rooms.

Approximate size of Transformer hall Cavern at EL 119 m will be 119 m length, 18.00 m width and 22.5 m height (Including secondary GIS).

The floor wise equipment layout plan is as stated below:

Machine Hall Floor at EL 173.00 m

- Phase Reversal Switches along with Generator Circuit Breakers (GCB) which will be installed and connected through Isolated Phase Bus Duct (IPBD)
- Main Transformers will be installed at the Transformer cavern

Generator-Motor Floor at EL 168.00 m

- Unit Control Boards (UCBs), Unit Auxiliary Boards (UABs)
- LT Distribution board with Dry Type Transformers
- Neutral Grounding Cubicles, Excitation Transformers and Panels
- Lubrication system etc.

Pump-Turbine Floor at EL 163.50 m

- Compressed Air System
- Oil Pressure Units for Governors
- Other Pump-Turbine Auxiliaries

Main Inlet Valve (MIV) Floor at EL 157.50 m

- Cooling Water Pumps
- Dewatering & Drainage Pumps
- Flood Water Pumps.
- Dewatering, Drainage and Flood Water Control Blocks

Drainage & Dewatering Gallery Floor at EL 148.00

- Dewatering Sump – Draft tubes will be connected with this sump through a network of valves & pipes.
- Drainage Sump – Seepage and drainage from various floors of power house will be collected to this sump.

24 kV Isolated Phase Bus Ducts (IPBD) interconnecting machine hall Floor with the Transformer cavern will be laid in individual bus duct tunnel of respective units. LAVT cubicles, Station Service (Auxiliary) connections with IPB shall also be installed in these tunnels. Beside these Two Bus Duct Tunnels, two (02) additional tunnels (One at the extended part of MAT on Service bay side and other on Unit–2 side) will be provided for inter-connecting Machine Hall cavern with Transformer Hall.

One cable tunnel of adequate size will be provided to accommodate 220 kV XLPE cables for transmitting power between Pothead Yard and 245 kV GIS / 220 kV Switchyard.

The access to turbine pit will be from pump-turbine Floor. Necessary hatches for erection and removal of MIV will be provided at various floors in the machine hall cavern.

The Main Access Tunnel (MAT) and Construction Adit Tunnel for the power house cavern shall be utilized as ventilation tunnel afterward

Two nos. of 325/50/10 Tonnes EOT Crane shall be installed in the power house cavern for tandem operation. One no. of 10T EOT Crane shall be installed in the GIS hall for handling the GIS equipment. One no. 50T EOT crane shall be installed in Transformer cavern for handling of Draft tube gates.

8.3 Brief Particulars of Pump-Turbine Equipment

8.3.1 Pump-Turbine

The Pump-turbine shall be of vertical shaft reversible Francis type coupled to Generator-Motor. 2 nos. of the Francis pump-turbine set each of 300 MW output rating while operating under rated head shall be installed.

The details of the hydraulic system of the generating units are as given below:

i) Upper Reservoir Levels

a)	Full Reservoir Level (FRL)	El. 490.00 m
b)	Minimum Drawdown Level (MDDL)	El. 470.00 m

ii) Lower Reservoir Levels

a)	Full Reservoir Level (FRL)	El. 212.00 m
b)	Minimum Drawdown Level (MDDL)	El. 202.90 m

iii) Head Loss

a)	Turbine mode	4.50 m
b)	Pump mode	4.50 m

iv) Head range as Turbine

a)	Maximum Head	282.60 m
b)	Minimum head	253.50 m
c)	Net design Head	269.87 m

v) Operating Head range as Pump

a)	Maximum Head	291.60 m

b)	Minimum Head	262.50 m
c)	Net design Head	278.87 m

vi) Turbine Basic Data

a)	Rated Output at rated head of 269.87 m	304.57 MW
b)	Turbine Output at 10% overload operation	330.00 MW
c)	Specific Speed	147 rpm
d)	Rated Speed	250 rpm
e)	Max. Discharge at rated head:	129.26 m3/sec
f)	Turbine center Line	160 m

vii) Pump Basic Data

a)	Specific speed at net pump head	33 m- m3/sec
b)	Rated speed	250 rpm

The Pump-Turbine shall be designed to have output of 0 to 100% rated output at the head ranges as specified above. And a stable pumping mode shall be obtainable within the design pump head specified above without pressure fluctuation and/or other faults. A design of highest efficiency for both turbine and pump shall be made.

The unit shall also be capable of operating in Spinning Reserve or Synchronous Condenser mode. To facilitate the same, necessary water supply system for runner gaps shall be provided. The machine shall be capable of Line Charging operation including charging of one Transmission line during total grid failure, towards restoration of grid power.

8.3.2 Speed Governor

Quantity: Two (2) sets

In pumping operation, the pump speed is governed by the motor, as the speed regulator circuit is not used. The speed governor shall continuously actuate and adjust the opening of guide vanes, initiated by the gate opening control device and water level measuring devices installed in the sequence control equipment, to obtain the best pumping efficiency corresponded with the pump head.

In generating operation, the speed governor shall be capable of automatic frequency control devices, deflective line control and guide vanes setting operation.

The electro-hydraulic governor shall have stable and accurate operation characteristics with Proportional-Integral-Derivative (PID) function. It shall be designed to have high sensitivity and high response characteristics.

Necessary protective devices including relays and contacts for control and alarm to lock the actuator and for quick stop of pump-turbine shall be provided in case of drop of hydraulic oil pressure for actuator, speed signal generator failure, DC power source failure or governor trouble. Whenever detecting the speed rise, the governor shall immediately send a closing signal of guide vane to make the speed stable regardless of the position of generator / motor circuit breaker and other control signals to the governor.

The oil pressure supply system shall be used for operation of the pump-turbine controlled by the speed governor.

8.3.3 Draft Tube Gates

Individual hoisting mechanism shall be provided for draft tube gate of each unit for quick closing, under the unbalanced condition of water pressure.

8.4 Brief Particulars of Generator-Motor Equipment

8.4.1 Generator-Motor

The Generator-Motor will be three phase alternating current synchronous generator motor of rotating field, vertical shaft type. Each of the four Generator-Motors shall have the following characteristics:

(a) Generator

i)	Rated capacity	300.00 MW
ii)	Power factor	0.9 lagging
iii)	Rated terminal voltage between phases	18 kV ± 10%
iv)	Frequency	50 Hz
v)	Phase	3
vi)	Synchronous Speed	250 rpm

vii)	Range of frequency	50 Hz ± 3%
viii)	Type of Generator-Motor	Semi Umbrella Type
ix)	Over load capacity (10%)	330 MW

(b) Motor

i)	Motor Capacity	327 MW
ii)	Power factor	0.95 leading
iii)	Rated terminal voltage between phases	18 kV
iv)	Frequency	50 Hz
v)	Phase	3
vi)	Speed	250 rpm

The voltage rating shall be optimized during preparation of bidding document / detailed project report stage.

Class F insulation will be provided for the armature winding and the field winding of the generator-motor.

The generator-motor will be provided with a conventional type of cooling system, i.e., air coolers. The air coolers shall have sufficient cooling capacity to maintain the air temperature.

8.4.2 Excitation System and AVR

The excitation equipment shall be static type potential-source, rectifier-type excitation system completes with digital type Automatic Voltage Regulator (AVR). Static excitation system shall be used for generating, motoring and synchronous condenser operation in the generating and motoring direction, back-to-back synchronous starting operation and static frequency converter (SFC) starting for pumping.

The AVR will be capable of covering 80% to 110% of the rated voltage of the generator at no-load operation. It will also be suitable for synchronous condenser operation.

When full load rejection occurs at generating mode due to external fault, the excitation system will be capable of depressing the terminal voltage rise of the generator-motor within 30 % of the rated voltage

under the conditions that the field breaker is in closed position and the speed rise of the generator-motor is within 45 % of the rated revolving speed.

8.4.3 Neutral Grounding Device for Generator-Motor

Neutral Grounding Resistor (NGR) system and Neutral Grounding Transformer (NGT) system are available for the neutral point grounding of the generator- motor.

Neutral Grounding Resistor (NGR) system would be suitable from the view point of cost and varying resistance characteristics with frequency during starting operation by back to back system. Hence, Neutral Grounding Resistor (NGR) system shall be used for grounding the neutral point of the generator-motor windings.

The Neutral Grounding Device shall consist of:

- Neutral Grounding Resistor (NGR)
- Disconnecting Switch
- Current Transformer

8.4.4 LAVT System

LAVT Cubicles shall include Surge Capacitors, Lightning Arrestors, Voltage Transformers and associated accessories.

8.4.5 Motor Starting Method

A. **Static Frequency Converter (SFC)**

One (01) set of Static Frequency Converter (SFC) with digital control type shall be used in common for two units of the generator / motor simultaneously and shall be connected to each generator / motor through the selective Disconnecting Switch, Circuit Breakers etc. to accelerate the machine in reverse direction for “pumping operation” up to rated speed by grid power. After synchronizing the machine with the grid SFC gets cut off.

B. Back to Back Starting Method

Beside SFC as main starting method of the motor (pumping mode), back-to-back (BTB) starting method as back-up option is recommended for the project.

In this case one unit will be started as generator and other will be in motor mode (by phase reversal switch operation) and ultimately synchronize with the grid to run the motor for pumping operation and generator will return to shut down. In this method, the generating unit and the pumping unit shall be selected in such a combination / manner that the units are connected to different penstocks / HRTs / TRTs.

8.5 Main Inlet Valve

Quantity: Two (02) Sets

The Main Inlet Valve is located between the Spiral Casing and the Penstock. Spherical type valve is generally recommended for a pumped storage plant because of its low loss, The flow capacity of the inlet valve will have sufficient to allow maximum flow of the pump-turbine discharge.

The inlet valve will be designed to safely withstand the stress due to the maximum hydraulic pressure obtainable including water thrust in the penstock and will be free from vibration and any abnormalities under the whole operating range of the pump-turbine including any transient conditions of operation.

The inlet valve will be designed to be capable of closing from fully opened position under the condition of maximum flow at every head.

A bypass valve of needle valve type will be furnished to the main inlet valve in order to balance the water pressure of both the penstock side and the pump-turbine side when the inlet valve is opened.

Both the main inlet valve and the bypass valve will be operated by pressure oil and the operating mechanism will consist of pressure-oil supply system, servomotor, rod and lever

The pressure oil supply system shall be used for operation of the inlet valve and the bypass valve.

8.6 Oil Treatment and Storage Equipment

The Oil Treatment and Storage Equipment of adequate capacity shall be used for storage and purifying the lubrication oil of the pump / turbine, generator / motor and pressure oil of the pressure oil supply

system. The oil treatment and storage equipment shall consist of oil filter presses, oil purifiers, oil storage tank and other required accessories.

Oil handling system

Oil handling system for transformer oil and lubricating oil for generating units will be provided with suitable piping, valves, tanks, purifiers etc. and shall be located such as to confirm the requirements of underground power house.

8.7 Compressed Air Supply System

A low pressure compressed air plant would be installed to meet the requirements for brake of generator and for shaft sealing system of turbine. A low pressure compressed air plant would also be installed to meet the requirement of the station pneumatic tools and other general purpose in the power house.

8.8 Cooling Water System

It is proposed to provide individual cooling water system for each unit to remove heat from generators and bearing oils through heat exchangers.

The water supply system shall be provided for replenishing the leakage water from the spiral case at depressing water level in draft tube at pump starting.

The cooling water for each main unit is supplied from the corresponding draft tube by an individual motor driven pump set. There is one regular use pump set for each main unit and one stand-by use pump set is provided for two main units. The stand-by use pump and regular use pumps are isolated by automatic operated valves.

The cooling water for each main unit is supplied from the corresponding draft tube by an individual motor driven pump set. There is one regular use pump set for each main unit and one stand-by use pump set is provided for two main units. The stand-by use pump and regular use pumps are isolated by automatic operated valves..

8.9 Dewatering and Water Drainage System

Dewatering system shall be provided in the power house for dewatering of unit for access to underwater parts.

8.10 Generator-Motor Main Circuit

Generator-Motor main circuit will consist of:

- Generator Circuit Breaker

24 kV, Indoor type, metal-enclosed, SF_6 circuit breaker will be installed between each Generator and respective Main Step-up Transformer for protection and synchronization (for remote closing and remote tripping or automatic tripping due to fault)

- Phase Reversal Disconnecting Switch

Rotational directions of pumping mode and generating mode of the unit are opposite. Therefore, a 24 kV Phase Reverse Disconnecting Switch Set of required current rating will be installed to change any 2 phases of 3 phases of main circuit in order to change the phase rotational direction at the generator-motor terminal to assure the desired direction of rotation for both generation mode and pumping mode.

- Pump Starting Disconnecting Switch

For each unit, 24 kV Disconnecting Switch for pump-starting by SFC will be provided between the generator-motor circuit breaker and the generator-motor.

- Insulating phase Bus (IPB)

Metal Enclosed Isolated Phase Bus (IPB) will be provided as the main bus (18 kV) between the terminals of generator-motor and the primary terminals of main step-up transformer.

- Braking System of the units

Both Electrical and Mechanical Braking System will be provided with each unit in order to reduce the time of stop operation. The electrical brake will begin to work at around 40% of the rated revolving speed. Below 10% of the rated revolving speed, the electrical brake will be released and the mechanical brake will begin to operate.

- Instrument Transformer

For protection and measuring of the main units, necessary current transformers and potential transformers will be installed.

8.11 Transformer Main Step-Up

8.11.1 Type and Rating

Single Phase; Rated Capacity: 123 MVA Quantity: 7 nos (including one spare) Rated Voltage: Primary 18 kV, Secondary 420 kV ± 5%, Indoor type, oil-immersed, single phase, forced oil forced water (OFWF) cooled, with on-load tap-changer (OLTC).

Each transformer cooling system shall consist of oil pump and cooler (heat exchanger) to form a unit cooling facility. The cooling water shall be supplied from the main water supply system when the generator-motor is in operation. The water fire extinguisher equipment shall be provided for each main transformer.

8.11.2 Surge Arrester for main Step-Up Transformer

GIS type Surge Arresters will be installed at the HV side of the step-up transformer.

8.11.3 Neutral Earthing of Main Step-Up Transformer

The neutral point of the secondary winding (HV Side) of each main step-up transformer will be solidly grounded.

8.12 Cables and Accessories

Single core 420 kV high voltage XLPE cables will be installed and connected from the underground secondary GIS to the outside switchyard through the cable tunnel for power evacuation between the main step-up transformers and the GIS / outdoor switchyard.

11 kV XLPE cables shall be used for connection from and to the 11 kV switchboards to be installed at different load centers in power house and switchyard.

1.1 kV Grade PVC insulated Copper / Aluminium power cables shall be used in the power house, transformer cavern, switchyard, Lower Dam, Upper Dam areas for supplying power to various auxiliaries, while for control cables 1.1 kV Grade PVC insulated copper cables will be employed.

The instrumentation cables used including Optical Fiber Cables (OFC) will be immune to electromagnetic interference. The number of pairs / cores required will be as per the requirement of the system.

8.13 420 KV GIS/Outdoor Switch Yard

Due to space and reliability constraints, 420 kV Gas Insulated Switchgear has been proposed and shall be housed on a floor located just above the transformers in the transformer cavern. Double bus bar arrangement is proposed for this project after giving due consideration to its reliability, stability, easy maintenance and accessibility. The GIS has total 7 bays comprises of 02 Nos. generator transformer bays, one bus coupler bay, and 4 Nos. outgoing feeder bays, 1 Shunt Reactor bay. Requirement of the shunt reactor shall only be finalised after detailed system studies during DPR. The outgoing feeders are directly going to the grid.

8.14 Control and Protection System

The system shall be applied for automatic control such as start, stop and protection of the pump-turbine combined with the control and protection system during all modes of operation such as turbine and pumping. All necessary components required for performing the automatic sequential control of the pump-turbine, and their main parts shall be accommodated inside the pump-turbine control board.

Beside the Local automatic control, remote control system which will be done through the Supervisory Control Monitorig and Data Acquisition System (SCADA) will also be employed in this project.

8.14.1 Control System

A supervisory control and data acquisition (SCADA) system will be provided for an efficient and economic plant operation. The power house will be designed to be operated with three levels of control:

- From the control room
- From the Unit control board located on the machine hall floor.
- From local control cubicles of each element located adjacent to the unit.

A main supervisory computer system supporting necessary man-machine interface will be located at the Main Control Room and separate local plant controllers will be provided for each main unit, station service circuit and 220 kV switchyard. The computer system and controllers will be linked by high-speed data transmission system.

8.14.2 Protection System

The protective relays will be provided for each units including its excitation transformer, station auxiliary system, main transformers, 220 kV XLPE cables, 220 kV switchgear etc.

The design of the protection scheme will be based on the general philosophy that all the protection equipment has a primary and back-up protection supplementing each other.

8.15 D.C. Supply System

A 220 volt DC System, with two sets(for redundancy) of battery banks of appropriate AH capacity would provide power for the control of switchgear, for the protection and control equipment, and for emergency lighting of the power house. The batteries would be provided with two battery chargers, each equipped with float and boost charging facility with all protective devices necessary to protect the system from damage. Distribution boards would be provided for feeding various DC loads of the units. A 48 V DC system with appropriate AH capacity battery bank will be installed for signalling and the PLCC system

8.16 AC Electrical Auxiliaries Supply System

8.16.1 Station Service Power

The station service supply is proposed to be taken through 11kV Local Distribution System. In addition, 2 nos. 0.415kV DG set of appropriate capacity shall also be provided for black start capability. The Station auxiliaries shall be fed through 2 nos. 18/0.415 kV, 1500 kVA transformers connected to Unit-1 & 2. The unit auxiliaries shall be fed through 18/0.415 kV, 1000 kVA transformers connected to each generator. The Station services shall be taken from 2 nos. 11/0.415, 1000 kVA transformer.

2 Nos. of 11/0.415 kV, 200 kVA Station Service Transformers (SST) for Upper Dam and Lower Dam shall be provided for meeting the power demand at dam area from 11 kV feeder from Local Distribution System

8.16.2 Motor Control Centre (MCC)

From 11 kV Bus, 3 nos. of 11 / 0.415 kV (Two nos. of 1 MVA and One no. 1.0 MVA) Dry type Distribution transformers will supply auxiliary power to Power House Motor Control Centre (MCC), Unit auxiliary equipment control center, Air compressor control center, drainage and dewatering pump control center, Oil supply system control system.

6 nos. of 11 / 0.415 kV Upper Dam and lower Dam auxiliary power and GIS / Switch Yard.

Each pump of various systems shall have the provision to be started and stopped manually by the respective switch mounted on the Motor Control Centre (MCC).

8.17 Grounding System

The power station will be provided with a complete earthing system. All exposed conductive parts and equipment in the power house, transformer hall & pothead yard will be connected to the grounding system. The grounding system shall be designed to minimize the “Step” and “Touch” potentials within acceptable limits. And separate grounding grid has to be provided for Electronics Equipment’s Earthing

8.18 EOT Crane

The Electrical Overhead Traveling Cranes are installed in the underground powerhouse for unloading, assembly, erection and future maintenance of the turbines, generators, and other mechanical and electrical equipment.

The heaviest equipment part to be handled by the main hoist will be the generator rotor. It is proposed to provide Two (02) nos. EOT cranes of 325/50/10 ton capacity EOT Crane with tandem operation. The capacity of crane however would need to be further examined in consultation with manufacturer of generating equipment. One (01) no. EOT Crane of 10 Ton capacity shall be installed at GIS hall and one (01) no. EOT Crane of 80 Ton capacity shall be installed in Transformer Room for Draft Tube Gate

8.19 Fire protection System

The Fire Protection System in the underground power house, main access tunnel, isolated phase bus duct tunnels, GIS / switchyard etc. shall be designed to timely detect the occurrence & quick extinguishing of fire break outs and prevention of spread of fire so as to minimize the extent of damage.

Water spray type Fire Extinguishing System shall be provided for all the generator-motor sets, main transformer, Station service system & SFC transformer. The fire extinguisher system shall detect fire inside the generator-motor barrel and transformer rooms instantaneously and accurately, and shall discharge water automatically by actuation both of the fire detector and protection relay, and also, by manual operation at the extinguisher panel.

8.20 Air Conditioning & Ventilation System

Power house would be provided with ventilation system as required for the underground power house , work areas and offices. An air conditioning system would be provided to maintain the control room at the required required level of temperature, humidity and comfort. The temperature and humidity level would be selected to suit the requirements of equipment and staff

8.21 Illumination System

Illumination system design shall be based on the principle of achievement of the desired illumination levels with minimum glare. The design shall result in the most energy-efficient and presentable illumination as per the latest international trends in underground power plants. While the majority of the luminaries will be AC powered, emergency lighting will be DC supplied from station battery system. The emergency lighting will be provided only for essential locations.

8.22 PLCC Equipment

PLCC system shall provide efficient sources and reliable information links to meet the communication need of protection, voice and data including SCADA system. It shall provide for distance protection and direct tripping for remote end breaker, signal transmission & speech communication between the power house/ GIS / sub-station and data communication to remote places through various frequency channels etc.

8.23 Communication System & Surveillance System

A suitable communication and surveillance system shall be installed in the power house complex to facilitate the communication and desired security in the power house area. Communication system comprises of the public address system and EPBAX equipment. The surveillance system would comprise of access control system and CCTV system equipment including all spaces of power house.

8.24 Electrical Equipment Testing Laboratory

Portable Electrical Testing Equipment will be provided to carry out normal testing of power house equipment. Separate room is proposed in the power house for Electrical Testing Laboratory for storage of portable equipment and to serve as a base for testing personnel. All the testing equipment should be PC compatible and of latest design.

8.25 Mechanical Workshop

A Mechanical Workshop will be provided in control block in machine hall cavern for routine maintenance as required for all works & will be equipped with drilling, welding, milling & lathe machines & other required machine tools.

8.26 Lift

Two numbers electrically operated lifts shall be in the control block for easy movement. The lift shall be designed for approximately a load of 10 persons.

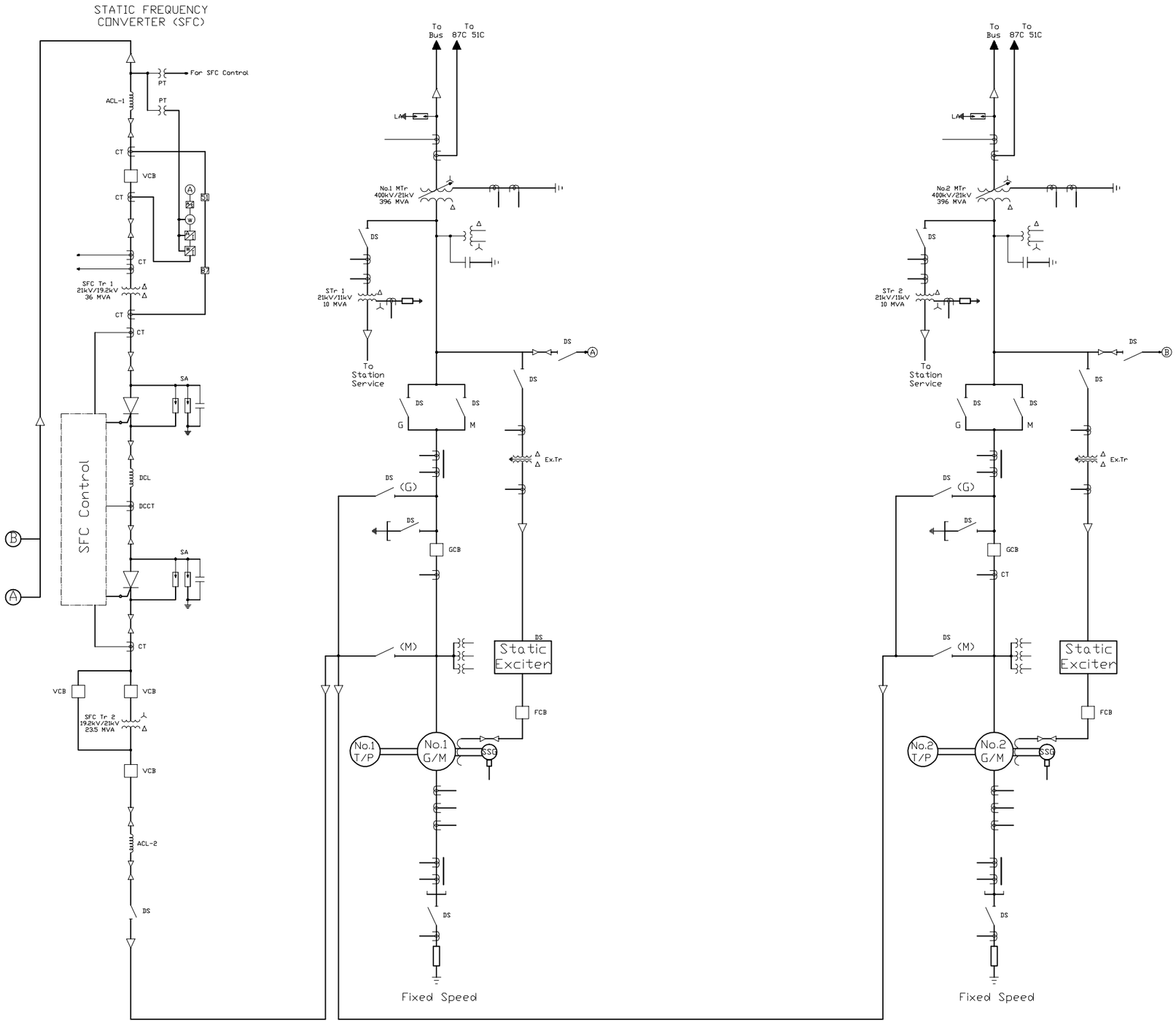
8.27 Power Evacuation Arrangement

The proposed Gandikota Pumped Storage Plant is of the installed capacity of 600 MW which consists of 2 units of 300 MW each.

Considering the n-1 contingency criteria, it is proposed to evacuate the power from 2 nos. D/C 220 kV transmission line which would be connected to nearest grid.

Further, possibility of LILO of the existing line or combined evacuation of the nearby upcoming projects can be explored during Detailed Project Report stage.

Annexure - 8



LEGENDS:-

SL. NO.	DESCRIPTION	SYMBOL
1.	DISCONNECTING SWITCH (DS)/ISOLATOR	
2.	LIGHTENING ARRESTOR (LA)	LA
3.	SURGE CAPACITOR(SC)	SC
4.	EARTH SWITCH (ES)	
5.	CIRCUIT BREAKER WITHOUT CLOSING RESISTOR OR CONTROL SWITCHING DEVICES	
6.	TRANSFORMER	
7.	CURRENT TRANSFORMER (CT)	
8.	POTENTIAL TRANSFORMER (PT)	
9.	OVER CURRENT RELAY	51
10.	PERCENTAGE DIFFERENTIAL RELAY	87
11.	STATION TRANSFORMER	STr
12.	EXCITATION TRANSFORMER	EX. Tr
13.	STATIC FRSQUENCY CONVERTER	SFC
14.	SPEED SIGNAL GENERATOR	SSG
15.	MAIN TRANSFORMER (18/400 kV)	MTr
16.	GENERATOR/MOTOR	G/M
17.	TURBINE/PUMP	T/P
18.	TRANSFORMER FOR SFC	SFC Tr
19.	GENERATOR CIRCUIT BREAKER	GCB
20.	POWER SUPPLY FOR SFC	Ⓐ Ⓑ
21.	AC REACTOR	ACL
22.	EXCITATION CIRCUIT BREAKER	Ex. CB

NOTES:-
1. THIS IS PFR STAGE DRAWING. THE SAME WILL BE UPDATED DURING DPR.

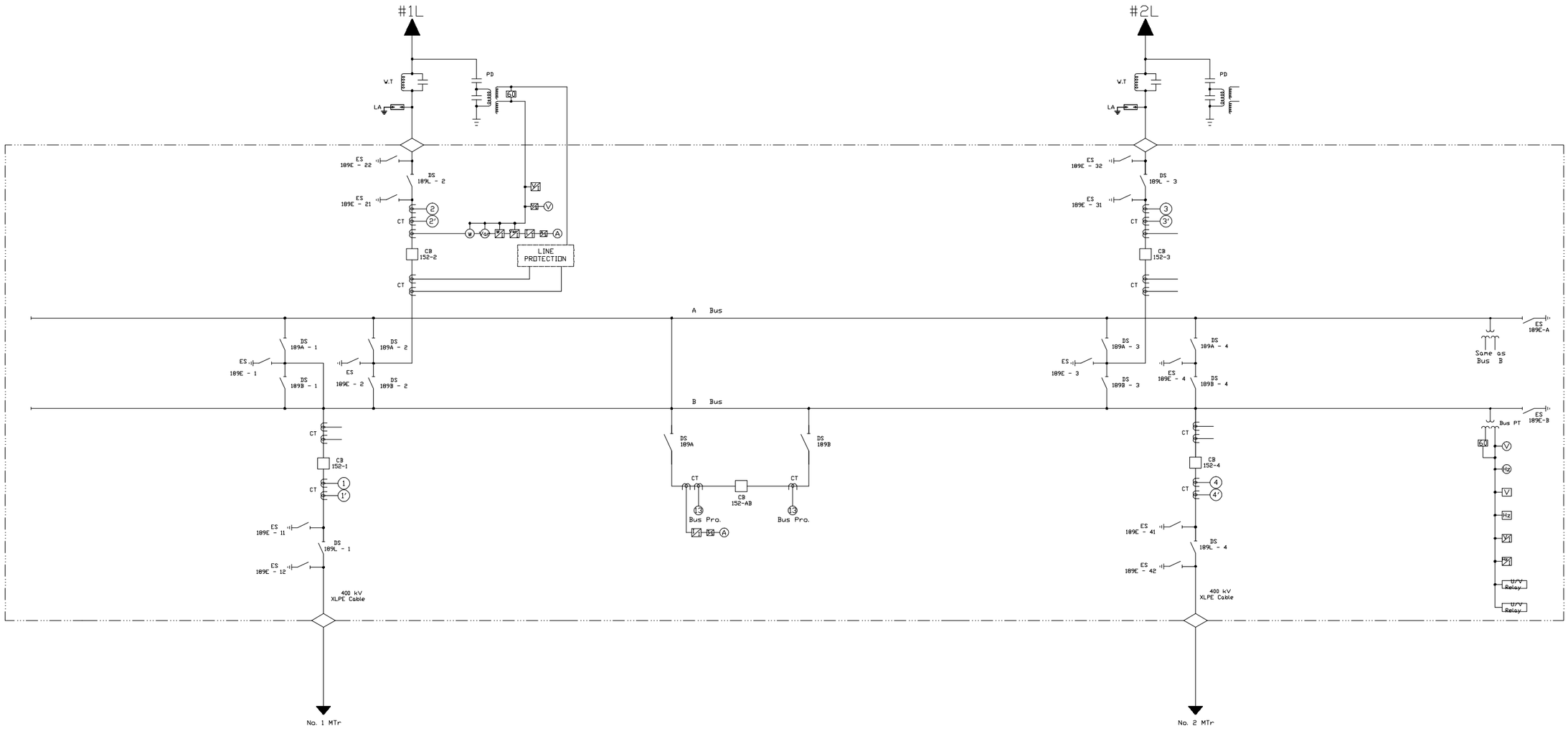
NEW & RENEWABLE ENERGY DEVELOPMENT CORPORATION OF ANDHRA PRADESH LTD. (NREDCAP)

CONSULTANTS
WAPCOS LIMITED
(A GOVT. OF INDIA UNDERTAKING)

GANDIKOTA PUMPED STORAGE PROJECT (600 MW)

SINGLE LINE DIAGRAM FOR MAIN CIRCUIT (2FS)

DEGN.- B.N.SARKAR	CHKD.- B.N.SARKAR	SUBM.-
DRAWN- R.DEY	REV.NO.-	APPD.-
DATE- FEB, 2020	DRG.NO.- WAP/D&RE/AP/GANDIKOTA/E&M/02	



LEGENDS:-

SL. NO.	DESCRIPTION	SYMBOL
1.	DISCONNECTING SWITCH (DS)/ISOLATOR	
2.	LIGHTENING ARRESTOR (LA)	LA
3.	SURGE CAPACITOR(SC)	SC
4.	EARTH SWITCH (ES)	
5.	CIRCUIT BREAKER WITHOUT CLOSING RESISTOR OR CONTROL SWITCHING DEVICES	
6.	WAVE TRAP	WT
7.	CURRENT TRANSFORMER (CT)	
8.	POTENTIAL TRANSFORMER (PT)	

400 kV GAS INSULATED SWITCHYARD (GIS)

NOTES:-
1. THIS IS PFR STAGE DRAWING. THE SAME WILL BE UPDATED DURING DPR.

NEW & RENEWABLE ENERGY DEVELOPMENT CORPORATION OF ANDHRA PRADESH LTD. (NREDCAP)

CONSULTANTS
WAPCOS LIMITED
(A GOVT. OF INDIA UNDERTAKING)

GANDIKOTA PUMPED STORAGE PROJECT (600 MW)

SINGLE LINE DIAGRAM FOR 400 kV SWITCHYARD

DEGN.- B.N.SARKAR	CHKD.- B.N.SARKAR	SUBM.-
DRAWN- R.DEY	REV.NO.-	APPD.-
DATE- JAN, 2020	DRG.NO.- WAP/D&RE/AP/GANDIKOTA/E&M/03	

CHAPTER-9: CONSTRUCTION PLANNING & SCHEDULE

CHAPTER – 9

9. CONSTRUCTION PROGRAMME AND SCHEDULE

9.1 General

Construction of proposed Gandikota Pumped Storage Scheme including erection of the two generating units is planned to be completed in a period of Four years and four months including Pre-construction works of eight months for creation of infrastructure facilities viz. additional Investigations, improvement of Road network and colonies.

Two shift working is considered economical for surface works. For underground works which do not follow normal pattern of shift working because of cyclic operations, three shifts working with minimum 15 hrs. or upto completion of cycle operations/day has been considered. Opting 25 working days in a month, shift wise scheduled working hours annually are adopted as follows:

Single Shift Work= 25 x 10 x 6 hrs. = 1500 hrs
Two Shift Work =25 x 10x 11hrs = 2750 hrs for Surface Works
Three Shift Work = 25x10 x 15 hrs = 3750 hrs
Three Shift Works = 25x10 x 18 hrs = 4500 hrs for Underground.

9.2 Main Components of the Project

9.2.1 Main Structure/ Components

The construction schedule has been detailed for major items of the following main structures/ components.

i. Civil Works

- Upper Reservoir/ Bund Type
- Upper intake
- Headrace tunnel cum pressure shaft
- Coffer dam
- Tailrace outlet structures
- MAT and construction Adits

- Draft Tube and Tailrace tunnel.
- Switch yard and Cable Tunnel
- Underground powerhouse and transformer cavern.

ii.Electrical Works

- E.O.T. cranes
- Supply and erection of T.G./Pumps sets 2 nos. 300 MW each
- 400 kv G.I.S. and bays equipment
- Main power transformers
- Other auxiliary electro-mechanical equipment

iii.Hydraulic equipment

- Intake gates
- Tailrace Outlet gates
- Draft Tube gates

9.2.2 Target Schedule

The total construction period is scheduled as follows.

Pre-construction Period	: 8 Months
Construction Period (Main Works)	: 3 Years and 10 Months
Total construction period	: 4 and ½ Years

The Programme is also exhibited in the form of a bar chart and is enclosed as **Annexure 9**

9.3 Infrastructure Facilities

The proposed Gandikota Pumped Storage Project is located in Kondapuram village of Kadapa district of Andhra Pradesh, India. The project falls in the Lat. N 14° 49' 47" & N 14° 48' 28" and Long. E 78° 13' 53" & E 78° 15' 5". It is located 93 KM towards west from District headquarters Kadapa. The altitude of the project area varies between 450m and 195m. The Upper reservoir is proposed by excavating a pit and constructing a bund at hilltop.

The Upper reservoir at present is not accessible but the Lower is accessible to nearest road network which is at about 5 km from NH-67. For power house approach tunnel, a new road is to be developed. Upper dam falls in forest area and there is no habitation. Lower dam is utilized for Irrigation, Drinking

water and fisheries purpose. The Upper reservoir is not accessible by road network. However, a road network is available at about 4-5 km from National highway. The rail head is Mangapattinam which is about 15 km approx. from project site. The nearest airport is Kadapa which is 100 km approx. from the project site.

Construction of infrastructure works will be taken up in first years. Construction power may be obtained from the existing grid, but a new sub-station needs to be developed. Construction/ improvement of project road and upgrading of existing road will be taken up immediately. The construction of office and residential buildings will be started in first year and be completed by second year. Construction of Project road shall be taken up first priority to complete within a year due to short length

Following provision is being kept for construction of offices and residential building at various sites:

- Permanent Office Buildings
- Temporary Office Buildings
- Temporary Site Offices
- Permanent Residential Buildings
- Temporary Residential Buildings

The construction of project colony, residential and other Non-residential building will be taken up from first months and completed all within eight months.

9.4 Upper Reservoir/Bund Type

As the upper reservoir is proposed on hilltop by making bund and excavating a pit till 1 m below the MDDL. The excavation for the Upper dam is proposed to be started in the 9th month of 1st year and will be spread over eight months i.e 4 months of 2nd year. Construction of dam embankment will be started in the 5th month of 2nd year and in continuation upto 4th month of 4rd year.

9.5 HRT & pressure shaft

Excavation of HRT from intake face will be taken up in the 1st month of second year after completing the open excavation of intake. The same will be completed in the 10th month of second year. The concreting/backfilling/ grouting/ rock bolting will be taken up simultaneously and completed in the 1st month of third year.

The excavation of horizontal pressure shaft will be taken up in the 2nd month of second year after completing the adit excavation which will start in 9th month of 1st year and spread over five months. The steel liners will be erected from 2nd month of third year and completed in the 1st month of fifth year.

9.6 Coffer Dam

As the proposed lower reservoir is existing, during construction stage, diversion method is being followed for lower reservoir, so that foundation excavation and embankment will be treated sequentially.

The construction of coffer dam is proposed to be started in the 9th month of first year and will be spread over six months upto 2nd month of 2nd Year.

9.7 Tailrace Tunnel/ Lower Intake/ TRT Outlet

Open Excavation of tailrace adit/outlet will start from 1st month of second year which will be completed in 3rd month of 3rd year and construction of Tailrace tunnel will be started in the 12th month of 2nd year and will be completed in 7th month of 3rd year.

9.8 Underground Powerhouse/ Transformer Caverns

Main Access tunnel to power house will be done by 6th month of second year and then the excavation of the power house cavern will be taken up in the 7th month of the second year and will be completed by 12th month of third year. The concreting will be taken up in the 7th month of the third year and will take 10months for completion.

9.9 Electro-Mechanical Works

Action for procurement of EOT cranes is proposed to be initiated in the 1st year itself. The entire process of inviting the tender, placing orders, manufacture, supply, erection and testing is planned to be carried out and completed upto 3rd year.

All the E&M equipments installation period for each pump/ turbine and generator/ motor has been considered as fifteen months

9.10 Impounding Schedule

Filling Time: As stated above, the 90% dependable flow is 4090.34 MCM and the quantity of water required to fill the upper reservoir is only 5.14 MCM. As the water demand is very less as compared to

water availability hence the filling time required for meeting 5.14 MCM of water by Lower Reservoir(existing) is insignificant and the same may be achieved with not much of a problem

Annexure - 9

Gandikota Pumped Storage Project (600 MW), Andhra Pradesh

Proposed Construction Schedule'

Sl. No.	Activities	Time (in months)	Ist Year												2nd Year												3rd Year												4th Year												5th Year					
			1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6
1	**Pre- Construction planning & Infrastructural Development**																																																						
i)	Preliminary	4																																																					
ii)	Land Acquisition	8																																																					
iii)	Procurement	8																																																				
iv)	Project Roads	8																																																				
v)	Project Colony/Office Buildings/ Construction Facilities	8																																																			
2	**Construction Phase**																																																					
i)	**Upper reservoir (Excavated pit type) and spillway**																																																				
	Excavation	8																																																				
	Construction of dam embankment	24																																																				
	Reservoir linning	12																																																				
ii)	**Intake Structures**																																																				
	Excavation	4																																																				
	Concreting	3																																																			
iii)	**HRT**																																																				
	Exacavation of HRT	10																																																			
	Grouting / Rock bolting	10																																																			
	Concrete Lining / backfilling	8																																																			
iv)	**Pressure Shaft**																																																				
	Adit to Pressure shaft (upper)	5																																																			
	Adit to Pressure shaft (lower)	5																																																		
	Excavation	12																																																			
	Erection of Steel Liners	24																																																			
v)	**Tailrace Tunnel & Outlet**																																																			
	Construction of Coffer Dam	6																																																		
	Excavation TRT	15																																																		
	Concreting TRT	8																																																		
	TRT Outlet	6																																																		
	Outlet Gate Shaft	3																																																		
vi)	**Power House Complex & Transformer Cavern**																																																		
	Main Access Tunnel to Powerhouse	10																																																		
	Cavern Excavation	18																																																		
	Cavern Concreting	10																																																		
vii)	**Electro-mechanical Equip.**																																																			
	E&M installation including commissioning	15																																																		
viii)	**Hydro-mechanical Equip.**																																																		
	HM Work including testing etc.	15																																																		

CHAPTER-10: POWER EVACUATION ARRANGEMENT

CHAPTER – 10

10. POWER EVACUATION ARRANGEMENT

10.1 Introduction

The power generated at Gandikota Pumped Storage Plant will be integrated with National grid and mostly be utilized in the peaking hour. The associated transmission system has been planned in accordance with guidelines and tentative planning of Central electricity Authority on transmission system for the region

10.2 Power Evacuation Arrangement

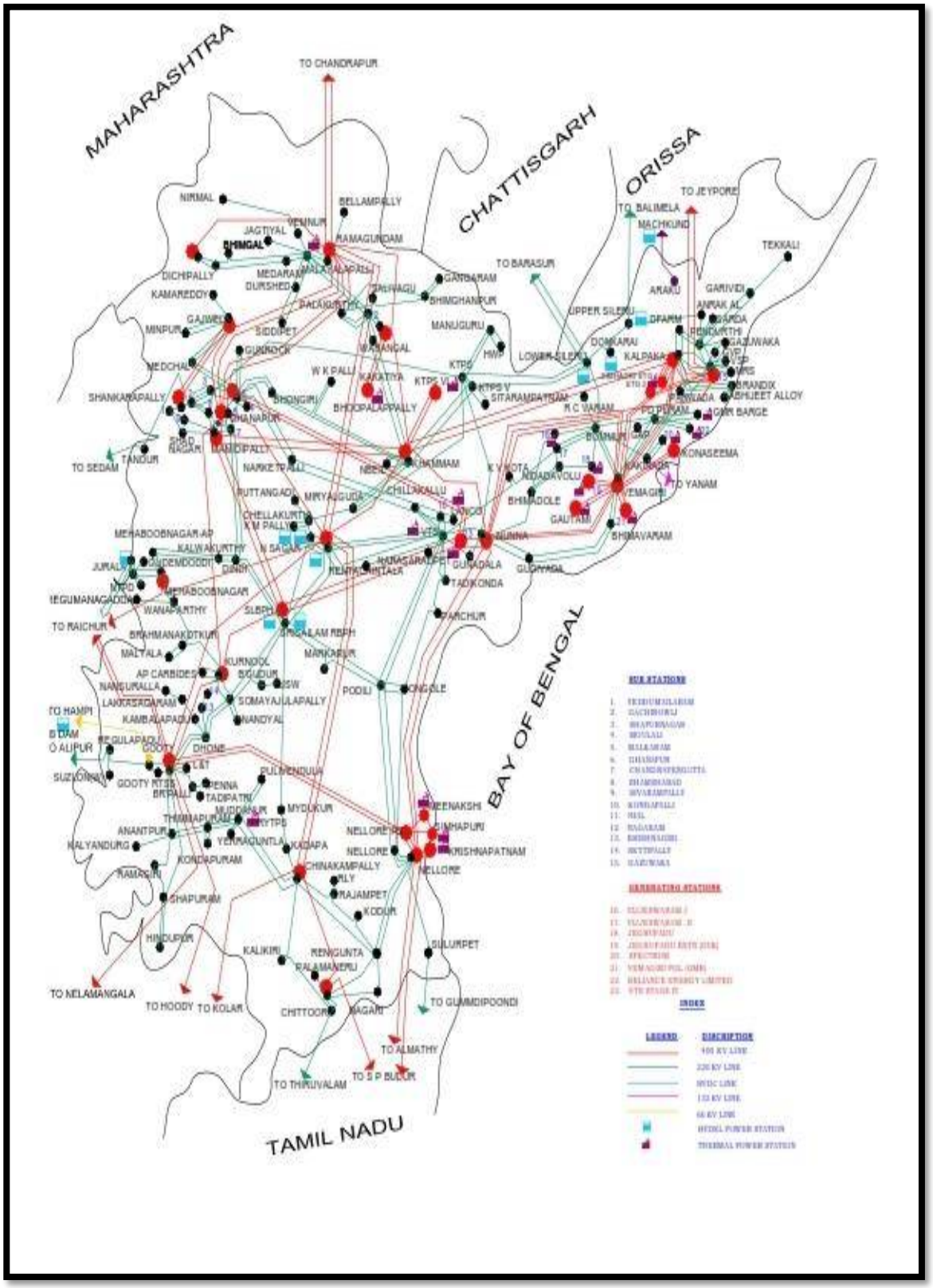
The proposed Gandikota Pumped Storage Plant is of the installed capacity of 600 MW which consists of 2 units of 300 MW each.

Therefore, considering the n-1 contingency criteria, it is proposed to evacuate the power from 2 nos. D/C 400 kV transmission line which would be connected to nearest grid.

Further, the following two options are proposed for evacuating the power of Gandikota Pumped Storage Project –

1. 2 nos. D/C Single Moose 400 kV Transmission Line from Gandikota Power House to 400 kV existing substation at Rayalseema 400kV Substation – Length of each line shall be approx. 27 km.
2. 2 nos. D/C Single Moose 400 kV Transmission Line from Gandikota Power House to 400 kV existing substation at Gooty – Length of each line shall be approx. 72 km.
3. Further, possibility of LILO of the existing line or combined evacuation of the nearby upcoming projects can be explored during Detailed Project Report stage.

However, a comprehensive load flow and Electromagnetic Transient study is necessary during FSR/DPR stage under peak demand load scenario and pumping power requirement during lean hours encompassing the above substations and different Pumped storage schemes of Andhra Pradesh and thereby setting up Substation & Transmission system effectively. The power evacuation scheme will be finalized at the FSR/DPR Stage.



Source: SRLDC

Fig.10.1 - Power Map of Andhra Pradesh

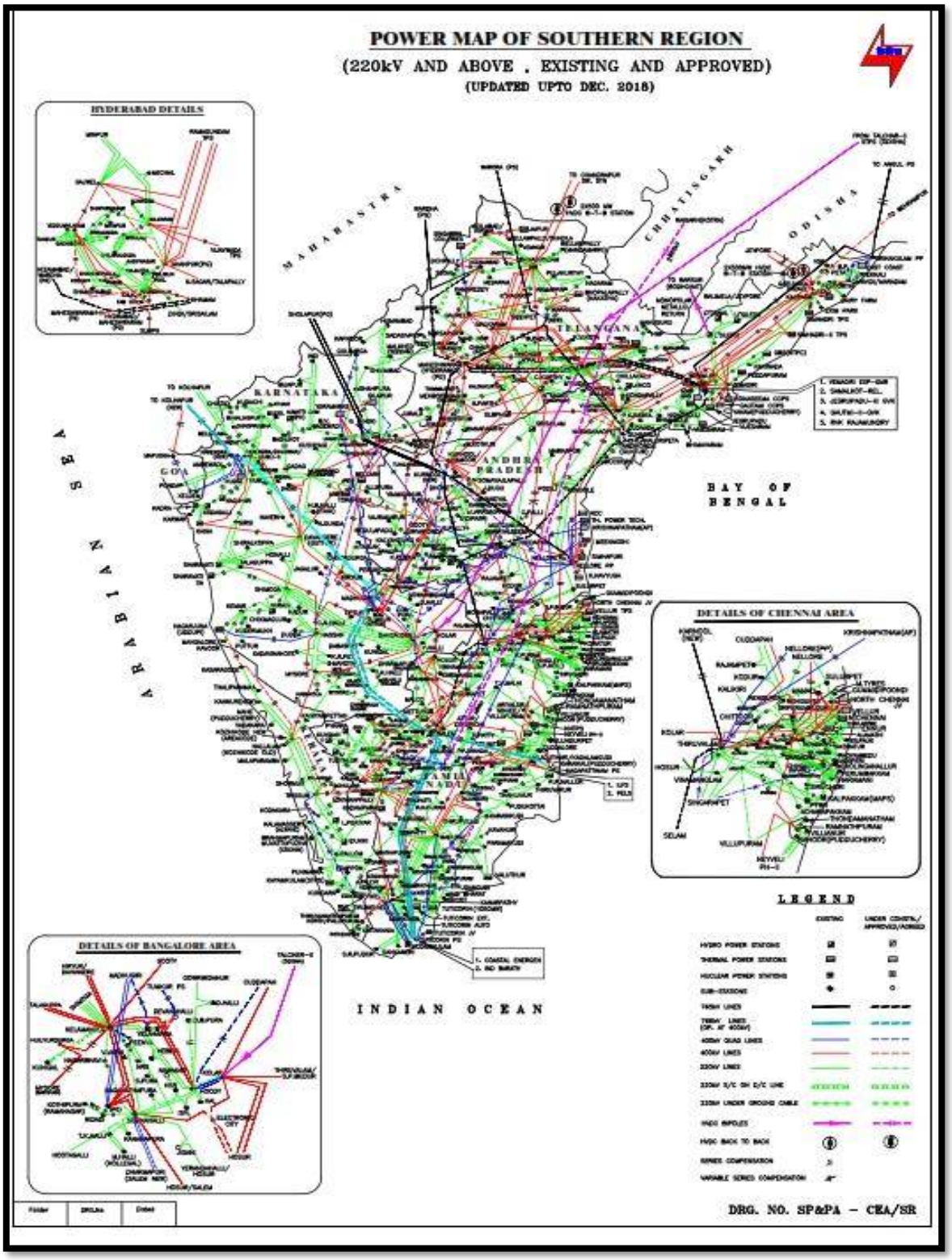


Fig.10.2 - Power Map of Southern Region Source: CEA

CHAPTER-11: COST ESTIMATE

CHAPTER – 11

11. COST ESTIMATE

11.1 Project Cost

A summary of the cost estimate, including direct and indirect charges for the Civil & Electro-mechanical works at Dec, 2019 Price Level has been worked out as given below:

Item	Estimated Cost (₹. Crores)
Civil Works	₹ 642.85
Electro-mechanical Works	₹ 1129.86
Total	**₹ 1,772.71**

The estimate has been prepared to arrive at the capital cost of Pumped Storage Project, Andhra Pradesh. The estimate is of Pre-feasibility level and has been prepared on the basis of "Guide Lines for preparation of cost estimates for River Valley Projects" published by Central Water Commission, Govt. of India, New Delhi. The Abstract of Cost is enclosed at in the relevant chapter of this report. The above cost includes the cost of Transmission. The detailed estimate is presented at **Annexure – 11**

11.2 Basis of Estimate

The estimate for Civil & Hydro-mechanical civil works have been prepared:

1. On the basis of Schedule of Rates of Andhra Pradesh for the year 2018-19 with the price escalation up to Dec, 2019 level. The rates which were not available in the Schedule of Rates have been adopted by updation to current price level from the recently approved H.E. Projects having similar parameters and working conditions. Moreover, items having SOR rates very less which are practical non-workable have also been revised.
2. The rates of materials are inclusive of GST as applicable.
3. Interest and escalation during construction period not considered.

Quantity estimate have been carried out by calculating the quantities of different work items involved. Unit rate corresponding to major item of works have been worked out by analysis of rate based on prevailing market rates. Some rates of major item of works, lump sum provision have been made based

on the other similar projects. The following guidelines have been referred for the preparation of this cost estimate:

- "Guidelines for preparation of project estimates for River Valley Projects" dated March 1997 by Central Water Commission, Govt. of India.
- "Guide Lines for preparation of Detailed Project Report of Irrigation and Multipurpose projects" 2010 by Central Water Commission, Govt. of India.

11.3 Classification of Civil Works into Minor Head/Sub Heads

The cost has been classified into direct and indirect charges and covered under the following minor heads:

Direct Charges

I. Works
II. Establishment
III. Tools and Plants
IV. Receipts and Recoveries on Capital Account

Indirect Charges

I. Capitalized Value of Abatement of Land Revenue
II. Audit and Account Charges

11.3.1 Direct Charges

11.3.1.1 I –Works

Current Cost = ₹ 597.82 Crores

The minor head I-Works has been subdivided in to the following detailed subheads:

A-Preliminary

Current Cost: ₹ 9.94 Crores

Under this head provision has been made for surveys and investigations to be conducted at FSR/DPR stage and later to arrive at the optimum of the project components. Provision for in-house Design & Engineering and consultancy charges has been kept under this head as 2% of cost of C & J Works.

B-Land

Current Cost: ₹ 30.00 Crores

This covers the provision for acquisition of land/lease charges for construction of the project, structures, colonies, offices etc. and the provision for Rehabilitation and Resettlement (R&R) of Project Affected Persons.

C- Works

Current Cost: ₹ 239.93 Crores

This sub-head covers the cost of Upper Reservoir and associated Hydro-mechanical equipment.

J- Power Plant Civil Works

Current Cost ₹ 257.08 Crores

This covers the cost of Civil Works of Power Tunnel Intake structures, Head Race Tunnel, Surge shaft/chamber, Pressure Shaft, Power House, Transformer Cavern & Tail Race Tunnel etc. along with associated Hydro-mechanical equipment.

K- Buildings

Current Cost: ₹ 19.88 Crores

A provision @ 4% of C-J Works has been made towards temporary and permanent buildings (both residential and non-residential) proposed to be built in colonies for various locations of the project area. The buildings included under the permanent category are all those buildings, which will be subsequently utilized during the state of running and maintenance of the project.

M- Plantation

Current Cost: ₹ 1.50 Crores

The provision under this head includes lump sum cost of plantation in colonies, along approach roads, landscaping and improvements of area around powerhouse.

O- Miscellaneous

Current Cost: ₹ 40.11 Crores

Under this head provision is generally made to cover the cost of the following miscellaneous works:

a) Capital cost of electrification, water supply, sewage disposal, firefighting equipment etc.
b) Repair and maintenance of electrification water supply, sewage disposal, medical assistance, recreation, post office telephone office security arrangements, firefighting, inspection vehicles, schools, transport of labour etc.
c) Other services such as laboratory testing, R&M of Guest House and transit camps, Community center and photographic instruments as well as R&M charges etc.

As the estimate is of Pre-feasibility level, percentage provision @ 2% of C-J works has been considered towards head O- Miscellaneous.

P- Maintenance

Current Cost: ₹.5.25 Crores

For maintenance of buildings, roads and other structures during construction period, provision @ 1% of C-works, J-Power Plant civil works, K- buildings R- Communication have been kept.

Q- Special T&P

Current Cost: ₹ 10.00 Crores

It is assumed that the work will be carried through Contracts and accordingly nominal provision for procurement of necessary equipment for taking up the work at the earliest by the contractor have been made. The total expenditure towards this will be recovered from the contractors and the same is credited under receipt and recoveries.

Adequate provision is made for inspection vehicles and cost for resale of vehicles is accounted for under receipt and recoveries.

R-Communication

Current Cost: ₹. 8.00 Crores

Provision under this head covers the cost of construction of roads and bridges for project works. The provision is Lump sum only at this stage based on preliminary assessments as detailing shall be done later on.

X-Environment and Ecology

Current Cost: ₹. 5.00 Crores

Provision under this head covers Bio-diversity Conservation, Creation of green belt, Restoration of Construction Area, Catchment Area Treatment and Compensatory Afforestation etc.

Y-Losses on Stock

Current Cost: ₹ 1.31 Crores

The provision under this head have been made @ 0.25% of the cost of I-Works less A-Preliminary, B-Land, Q-Miscellaneous, M-Plantation, P-Maintenance, Q-Special T&P and Environment and Ecology.

11.3.1.2 II-Establishment

Current Cost: ₹ 34.07 Crores

Provision for establishment including establishment of cost control cell at the project and Head Quarter Level has been made as per "Guide lines for Preparation of Detailed Project Report of Irrigation and Multipurpose Project" by CWC @ 6% of I-Works less B-Land

11.3.1.3 III- Tools &Plants

Current Cost: ₹.5.98 Crores

The provision is distinct from that under Q-Special T&P and is meant to cover cost of survey instruments, camp equipment and other small tools & plants.

11.3.1.4 IV-Receipt &Recoveries

Current Cost's. (-) ₹ 2.50 Crores

The provision under this head cover the estimated recoveries by way of resale of temporary buildings, transfer of construction equipment, inspection vehicles, generators etc. Provision @ 25% of Q- Special T&P has been considered towards IV=Receipt & Recoveries.

11.3.2 Indirect Charges

Current Cost: ₹.7.48 Crores

Provisions under this head have been made for capitalized value of abatement of land revenue. Besides, provision for Audit & Account Charges has been made at 1% of the cost of I-Works.

11.4 Electro-Mechanical Works

Current Cost: ₹ 1129.86 Crores

The total cost of Electro-Mechanical works at Dec, 2019 level works out to be: ₹ 1129.86 Crores, which includes, the cost of main Electro-Mechanical equipment such as turbines, generators, transformers etc. based on the prevailing market prices in India and abroad. Suitable provision for transportation, erection and commissioning charges, freight and insurance etc. have been adequately made as per general guidelines issued by CEA. Provision for establishment and Audit and Account charges for the electro-mechanical works have also been made under this cost separately.

Annexure - 11

GANDIKOTA PUMPED STORAGE PROJECT (600 MW)		
GENERAL ABSTRACT OF COST		
Sl. No.	**DETAILED HEAD OF WORKS**	**Amount (₹ in Crores)**
A	**CIVIL WORKS**	
1	**DIRECT CHARGES**	
	I-WORKS	
	A-Preliminary	₹ 9.94
	B-Land	₹ 30.00
	C-Works including HM Works	₹ 239.93
	J-Power Plant Civil Works	₹ 257.08
	K-Building (4% of C-J Works)	₹ 19.88
	M-Plantation LS	₹ 1.50
	O-Miscellaneous	₹ 9.94
	P-Maintenance during construction @1% of I Works-(A+B+O+M+Q+X+Y)	₹ 5.25
	Q-Special T&P	₹ 10.00
	R-Communication	₹ 8.00
	X-Environment & Ecology	₹ 5.00
	Y-Losses on Stock @0.25% of C,J,K & R	₹ 1.31
	Total of I-Works	**₹ 597.82**
	II-ESTABLISHMENT @ 6% OF (I-WORKS LESS B LAND)	**₹ 34.07**
	III-TOOLS & PLANTS(1% of I-Works)	**₹ 5.98**
	IV-SUSPENSE	**₹ 0.00**
	V-RECEIPT & RECOVERIES (-)	**-₹ 2.50**
	Total of Direct Charges	**₹ 635.37**
2	**Indirect Charges**	
	(a) Capitalised value of abatement of land revenue @ 5% of cost of culturable land	₹ 1.50
	(b) Audit & Account Charges (@ 1% of I-Works)	₹ 5.98
	Total of Indirect Charges	**₹ 7.48**
	Total Cost (Direct charges + Indirect Charges)	**₹ 642.85**
	Total Cost Civil Works	**₹ 642.85**
A	**Civil Works**	**₹ 642.85**
B	**Electo-Mechanical Works**	**₹ 1,129.86**
	Total Cost	**₹ 1,772.71**

CHAPTER-12: ECONOMIC EVALUATION

CHAPTER – 12

12. ECONOMIC EVALUATION

12.1. General

The economic and financial evaluation of the Gandikota Pumped Storage Project, Andhra Pradesh has been considered as per the standard guidelines issued by Central Electricity Authority and the norms laid down by the Central Electricity Regulatory Commission (CERC) for Hydro projects have been kept in view in this regard.

12.2. Project Benefits

The scheme would afford on annual peaking period energy generation of 1113.25 GWh annually. For assessing the tariff, design energy generation of 1057.59 GWh, calculated with 95% capacity availability in a normal dependable year, has been adopted. The project would provide 600 MW of 5 hours and 05 minutes daily peaking capacity benefits.

12.3. Capital Cost

The project cost has been estimated at ₹ **1772.71 Crores** without IDC as given below:

1.	Cost of civil works	=	₹. 642.85 Crores
2.	Cost of Electrical/Mechanical works	=	₹. 1129.86 Crores
	Total	=	**₹. 1772.71 Crores**

12.4. Mode of Financing

The project is proposed to be financed with a debt equity ratio of 70:30. An interest rate of 10% on the loan component has been considered for the financial analysis of the project. The interest on the working capital is taken as 11.92%.

12.5. Phasing of Expenditure

The project is scheduled to be completed in 5 years from the financial closure in all respects. The phasing of the expenditure worked out on the basis of proposed construction programme is summarized in Table

12.1.

Table – 12.1

Phasing of Expenditure

Half Year	Capital Expenditure (₹. Crores)
Up-to 1st Half Year	**90.19**
2nd Half Year	**138.44**
3rd Half Year	**188.38**
4th Half Year	**285.15**
5th Half Year	**385.32**
6th Half Year	**308.62**
7th Half Year	**319.42**
8th Half Year	**195.32**
9th Half Year	**157.07**
Total	**2067.91**

12.6. Financial Analysis

12.6.1 Basic and Normative Parameters

The following normative parameters have been adopted for working out the financial analysis of the project.

i. The estimated capital cost of ₹. 2067.91 Crores including the Interest During Construction as ₹. 295.20 Crores
ii. Annual gross energy generation of 1113.25 GWh considering 365 days generation in a year.
iii. Operation & maintenance expenses (including insurance) @ 3.5% of the project cost in the first year with 4.77% escalation every year.
iv. Depreciation allowed @ 5.28 % of the project cost excluding land cost for first 14 years and remaining depreciation is spread over the balance life i.e. 21 years on an average basis keeping 10% salvage value of the assets.

v. Auxiliary consumption i.e. quantum of energy consumed by auxiliary equipment of the generating station and transformer loss @ 1.25 % of the energy generated.
vi. Interest on working capital @ 11.92%.
vii. Interest during construction has been worked out based upon the interest rates @ 10 %. The computations are given in Annexure-1 for present day capital cost.
viii. Return on equity @ 15.50%
ix. Pump-Generation Cycle efficiency @ 80.05 %
x. Pumping Energy Required 1390.65 GWH
xi. Off-peak Energy Rate (₹/kWh) @ ₹. 3/-
xii. MAT @ 17.01 %
xiii. Corporate Tax – 25.17%
xiv. Tax Holiday – 10 Years
xv. Project Life – 40 Years

12.6.2 Assessment of Tariff

Based upon the parameters given above, the sale rate of energy at bus bar has been computed in **Annexure-12.1**

The sale rate applicable in the first year and levellised tariff is indicated below.

Sl. No.	Off Peak Energy Rate (₹/kWh)	First Tariff (₹/kWh)	Levellized Tariff (₹/kWh)	conversion cost of the project (excluding pumping cost) (₹/kWh)
1	3	8.21	7.72	3.67

However, Levelized tariff has also been calculated considering the project life 50 & 60 years as well and comes out as ₹/kWh 7.74 & ₹/kWh 7.76 respectively

Annexure - 12

Annexure-1

GANDIKOTA PSP (2x300=600 MW)

INTEREST DURING CONSTRUCTION (IDC)

1	**Cost of Civil Works**	**INR**	**642.9**	Cr.	
2	**Cost of E&M Works**	**INR**	**1129.9**	Cr.	
3	**Total Cost of the Project**	**INR**	**1772.7**	Cr.	
4	**Interst Rate on Loan**		**10.0**	%	per annum
5	**Equity**		**30.0**	%	
6	**Loan**		**70.0**	%	
7	**CERC Gudelines followed**		**2019-24**		

Period	Phasing of expendtiure	Hard Cost	Equity	Loan	IDC	Loan for IDC	Equity for IDC	Outstanding Loan
Half year	%	INR Cr.	INR Cr.	INR Cr.	INR Cr.	INR Cr.	INR Cr.	INR Cr.
1	5	88.64	26.59	62.04	1.55	1.09	0.47	63.13
2	7.5	132.95	39.89	93.07	5.48	3.84	1.64	160.04
3	10	177.27	53.18	124.09	11.10	7.77	3.33	291.90
4	15	265.91	79.77	186.13	19.25	13.47	5.77	491.51
5	20	354.54	106.36	248.18	30.78	21.55	9.23	761.23
6	15	265.91	79.77	186.13	42.71	29.90	12.81	977.27
7	15	265.91	79.77	186.13	53.52	37.46	16.06	1200.86
8	7.5	132.95	39.89	93.07	62.37	43.66	18.71	1337.59
9	5	88.64	26.59	62.04	68.43	47.90	20.53	1447.54
		1772.71	531.81	1240.90	295.20	206.64	88.56	

Hard Cost	**INR**	**1772.71**	**Cr.**	**Equity**	**INR**	**620.37**	**Cr.**
IDC	**INR**	**295.20**	**Cr.**	**Loan**	**INR**	**1447.54**	**Cr.**
Total Capital Cost	**INR**	**2067.91**	**Cr.**	**Total Capital Cost**	**INR**	**2067.91**	**Cr.**

Annexure-2

GANDIKOTA PSP (2x300=600 MW)

S.No	Parameters	Unit	Value		S.No	Parameters	Unit	Value		S.No	Parameters	Unit	Value	S.No	Parameters	Unit	Value
1	Installed Capacity	MW	600.00		11	ROE	%	15.50		14	Interest rate on W.C	%	11.92	22	Equity	INR in Crs	620.37
2	Normative availability	%	95.00		12	Working capital				15	O&M Expenses	%	3.50	23	Loan	INR in Crs	1447.54
3	Annual Energy Generation	GWh	1113.25														
4	**Annual Energy Generation @ 95% availability**	GWh	**1057.59**			i) Spares(% of O&M)	%	15.00		16	O&M Escalation rate	%	4.77	24	interest	%	10.00
5	Secondary Energy	GWh	0.00			ii) O&M expenses	Months	1.00		17	Discount Rate	%	10.36	25	Repay P	Yrs	14.00
6	Transformation losses	%	0.50			iii) Receivables	days	45.00		18	Depreciation Rate	%	5.28	26	Total cost	INR in Crs	2067.91
7	Auxiliary Consumption	%	0.70		13	i) MAT		17.01%		19	Max Dep Allowed	INR Cr.	1861.12	27	Project Life	Years	**40**
8	Transmission losses	%	0.00			II) Tax		25.17%		20	Energy Required for pumping	GWh	1390.65				
9	Free Power	%	0.00			III) Tax holiday	years	10.00		21	Rate for off peak energy	INR	3.00				
10	Net Saleble energy	GWh	1044.93										per unit				

Year	ROE	O&M	Depreciation	Outstanding Principal	Intt on Loan	Loan Principle Paid	Loan Installment	W.C				Intt on W.C	Charges for Pumping	Annual Expenses	Energy		Tarrif	Discount Factor	Discounted Tariff
								O&M	Spares	Recievables	Total				Free	Sold			
	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	GWh	GWh	INR/KWh		INR/KWh
1	115.87	62.04	109.19	1447.54	139.29	109.19	248.48	5.17	9.31	105.77	120.25	14.33	417.20	857.92	0.00	1044.93	8.21	1.00	8.21
2	115.87	65.00	109.19	1338.35	128.38	109.19	237.56	5.42	9.75	104.79	119.95	14.30	417.20	849.93	0.00	1044.93	8.13	0.91	7.37
3	115.87	68.11	109.19	1229.16	117.46	109.19	226.64	5.68	10.22	103.82	119.71	14.27	417.20	842.08	0.00	1044.93	8.06	0.82	6.62
4	115.87	71.35	109.19	1119.98	106.54	109.19	215.72	5.95	10.70	102.87	119.52	14.25	417.20	834.39	0.00	1044.93	7.99	0.74	5.94
5	115.87	74.76	109.19	1010.79	95.62	109.19	204.81	6.23	11.21	101.94	119.38	14.23	417.20	826.86	0.00	1044.93	7.91	0.67	5.33
6	115.87	78.32	109.19	901.61	84.70	109.19	193.89	6.53	11.75	101.03	119.31	14.22	417.20	819.49	0.00	1044.93	7.84	0.61	4.79
7	115.87	82.06	109.19	792.42	73.78	109.19	182.97	6.84	12.31	100.15	119.29	14.22	417.20	812.31	0.00	1044.93	7.77	0.55	4.30
8	115.87	85.97	109.19	683.24	62.86	109.19	172.05	7.16	12.90	99.28	119.35	14.23	417.20	805.31	0.00	1044.93	7.71	0.50	3.87
9	115.87	90.07	109.19	574.05	51.95	109.19	161.13	7.51	13.51	98.45	119.46	14.24	417.20	798.51	0.00	1044.93	7.64	0.45	3.47
10	115.87	94.37	109.19	464.87	41.03	109.19	150.21	7.86	14.16	97.63	119.65	14.26	417.20	791.91	0.00	1044.93	7.58	0.41	3.12
11	128.50	98.87	109.19	355.68	30.11	109.19	139.29	8.24	14.83	98.43	121.50	14.48	417.20	798.35	0.00	1044.93	7.64	0.37	2.85
12	128.50	103.59	109.19	246.49	19.19	109.19	128.38	8.63	15.54	97.67	121.84	14.52	417.20	792.18	0.00	1044.93	7.58	0.34	2.56
13	128.50	108.53	109.19	137.31	8.27	109.19	117.46	9.04	16.28	96.94	122.26	14.57	417.20	786.26	0.00	1044.93	7.52	0.31	2.31
14	128.50	113.71	109.19	28.12	1.41	28.12	29.53	9.48	17.06	96.74	123.27	14.69	417.20	784.69	0.00	1044.93	7.51	0.28	2.08
15	128.50	119.13	12.79	0.00	0.00	0.00	0.00	9.93	17.87	85.20	113.00	13.47	417.20	691.09	0.00	1044.93	6.61	0.25	1.66
16	128.50	124.81	12.79	0.00	0.00	0.00	0.00	10.40	18.72	85.93	115.06	13.71	417.20	697.01	0.00	1044.93	6.67	0.23	1.52
17	128.50	130.77	12.79	0.00	0.00	0.00	0.00	10.90	19.61	86.70	117.21	13.97	417.20	703.22	0.00	1044.93	6.73	0.21	1.39
18	128.50	137.00	12.79	0.00	0.00	0.00	0.00	11.42	20.55	87.50	119.47	14.24	417.20	709.73	0.00	1044.93	6.79	0.19	1.27
19	128.50	143.54	12.79	0.00	0.00	0.00	0.00	11.96	21.53	88.34	121.83	14.52	417.20	716.55	0.00	1044.93	6.86	0.17	1.16
20	128.50	150.39	12.79	0.00	0.00	0.00	0.00	12.53	22.56	89.22	124.31	14.82	417.20	723.69	0.00	1044.93	6.93	0.15	1.06
21	128.50	157.56	12.79	0.00	0.00	0.00	0.00	13.13	23.63	90.14	126.91	15.13	417.20	731.17	0.00	1044.93	7.00	0.14	0.97
22	128.50	165.08	12.79	0.00	0.00	0.00	0.00	13.76	24.76	91.11	129.63	15.45	417.20	739.01	0.00	1044.93	7.07	0.13	0.89
23	128.50	172.95	12.79	0.00	0.00	0.00	0.00	14.41	25.94	92.12	132.48	15.79	417.20	747.23	0.00	1044.93	7.15	0.11	0.82
24	128.50	181.20	12.79	0.00	0.00	0.00	0.00	15.10	27.18	93.18	135.46	16.15	417.20	755.83	0.00	1044.93	7.23	0.10	0.75
25	128.50	189.84	12.79	0.00	0.00	0.00	0.00	15.82	28.48	94.30	138.59	16.52	417.20	764.85	0.00	1044.93	7.32	0.09	0.69
26	128.50	198.90	12.79	0.00	0.00	0.00	0.00	16.57	29.83	95.46	141.87	16.91	417.20	774.29	0.00	1044.93	7.41	0.09	0.63
27	128.50	208.38	12.79	0.00	0.00	0.00	0.00	17.37	31.26	96.68	145.30	17.32	417.20	784.19	0.00	1044.93	7.50	0.08	0.58
28	128.50	218.32	12.79	0.00	0.00	0.00	0.00	18.19	32.75	97.96	148.90	17.75	417.20	794.56	0.00	1044.93	7.60	0.07	0.53
29	128.50	228.74	12.79	0.00	0.00	0.00	0.00	19.06	34.31	99.30	152.67	18.20	417.20	805.42	0.00	1044.93	7.71	0.06	0.49
30	128.50	239.65	12.79	0.00	0.00	0.00	0.00	19.97	35.95	100.70	156.62	18.67	417.20	816.80	0.00	1044.93	7.82	0.06	0.45
31	128.50	251.08	12.79	0.00	0.00	0.00	0.00	20.92	37.66	102.17	160.76	19.16	417.20	828.73	0.00	1044.93	7.93	0.05	0.41
32	128.50	263.06	12.79	0.00	0.00	0.00	0.00	21.92	39.46	103.71	165.09	19.68	417.20	841.22	0.00	1044.93	8.05	0.05	0.38
33	128.50	275.61	12.79	0.00	0.00	0.00	0.00	22.97	41.34	105.33	169.63	20.22	417.20	854.31	0.00	1044.93	8.18	0.04	0.35
34	128.50	288.75	12.79	0.00	0.00	0.00	0.00	24.06	43.31	107.02	174.39	20.79	417.20	868.03	0.00	1044.93	8.31	0.04	0.32
35	128.50	302.53	12.79	0.00	0.00	0.00	0.00	25.21	45.38	108.79	179.38	21.38	417.20	882.39	0.00	1044.93	8.44	0.04	0.30
36	128.50	316.96	12.79	0.00	0.00	0.00	0.00	26.41	47.54	110.64	184.60	22.00	417.20	897.45	0.00	1044.93	8.59	0.03	0.27
37	128.50	332.07	12.79	0.00	0.00	0.00	0.00	27.67	49.81	112.59	190.07	22.66	417.20	913.22	0.00	1044.93	8.74	0.03	0.25
38	128.50	347.91	12.79	0.00	0.00	0.00	0.00	28.99	52.19	114.63	195.81	23.34	417.20	929.74	0.00	1044.93	8.90	0.03	0.23
39	128.50	364.51	12.79	0.00	0.00	0.00	0.00	30.38	54.68	116.76	201.81	24.06	417.20	947.05	0.00	1044.93	9.06	0.02	0.21
40	128.50	381.90	12.79	0.00	0.00	0.00	0.00	31.82	57.28	119.00	208.11	24.81	417.20	965.19	0.00	1044.93	9.24	0.02	0.20
			1861.12			**1447.54**												**10.45**	80.62
	L. T(INR/Kwh)=	**7.72**																	

CHAPTER-13: CONCLUSION & RECOMMENDATION

CHAPTER – 13

13. CONCLUSION AND RECOMMENDATION

The objective of present study is to initial screening study to explore and assess the prima facie possibility of constructing a pumped storage project. In spite of the limited time and paucity of data WAPCOS has carried out the preliminary analysis and studies with suitable assumptions and prepared the Present report. Following broad conclusions are drawn and recommended for further consideration by the competent authority at PFR/DPR stage

13.1 Technical Merits of The Project:

- The Gandikota PSP upper dam site have been selected after due diligence and based on the available digital data using latest software and techniques.
- Hydrological studies of the project suggest that the water requirement for filling upper reservoir is very less as compared to its availability hence filling of reservoir for meeting 5.14 MCM of water at lower reservoir will not be much of a problem.
- No interference is envisaged with hydrological regime of the river
- Based on the preliminary geological studies it can be concluded that **No geological** surprise is envisaged. Geological setup is conducive for underground works.
- Land requirement of **350 Acres** is on lower side considering the size of the project of 600 MW.
- Based on preliminary stage studies, it is envisaged that the majority of land is Government and minimum private land is expected.
- Based on the present level of studies no R&R issues seems to be involved.
- The per MW cost is approx. ₹ 2.95 crores only which is very attractive.
- The annual generation per acres of forest land is 3.18 Gwh / acres which is very attractive proposition and may be eligible for preferential consideration
- The conversion cost of the scheme is ₹ 3.67 which can be considered as suitable for active consideration.

- It may be pertinent to mention here that the availability of pumping power in the form of renewable power form Solar, Wind etc. is likely to increase. In such scenario more cycle operation can be examined to increase the peak generation and as a result the viability of the scheme can be enhanced many folds. However, this aspect can be studied in detail at PFR/DPR stage.

13.2 Area of concerns of The Project:

Since the Lower reservoir is an existing reservoir the following aspects needs to be examined at DPR stage

- The hydrographic survey of existing reservoir to confirm Levels
- To reconfirm mandatory requirement for construction of Intake structure
- To reconfirm the operational cycle based on detailed simulation with updated Area/capacity curve
- Site specific methodology for intake construction in existing Gandikota reservoir

13.3 Need of Gandikota Pumped Storage Project

- In view of mandatory large injection of Renewables in to the grid in near future, AP needs advance planning to integrate it and Gandikota PSP can be useful in this regard.
- Pumped Storage is the **natural Battery** with longer useful life and environmentally friendly proposition of Energy Storage.
- It is learnt that in view of large envisaged injection of renewables various support measures are in active consideration of the Government and likely to be implemented such as differential tariff for peak and off peak, incentive for ancillary services for the operation of grid, black start facility etc.
- There is a precedence and current trend in favour of Pumped Storage projects. West Bengal has already constructed Purulia PSP (900 MW) and Turga PSP (1000 MW) is now under pre-construction. **Other states** are also going for PSP in an accelerated manner.

- Based on the available data it can be said that in view of overall trend of generation planning and demand, AP would be needing source to generate peak power to improve Hydro: Thermal Mix and provide much needed balance to renewable in year 2025-26.
- Gandikota Pumped Storage Project involves minimum and simple civil works and could be completed in 4 and ½ years. The project would afford an annual design energy generation of 1113.25 GWh per year. The cost per MW installed works out as approx. ₹ 2.95 crore / MW.
- **This report indicates that Gandikota PSP scheme has merits from technical and financial aspects.**

In view of above Gandikota Pumped Storage Project is recommended for taking up for FSR / DPR.

A project information sheet for Gandikota PSP is presented at **Annexure- 13**

Annexure - 13

I. SITES ON RIVER																					
DISTRICT	LOCATION	Rated HEAD(m)	Upper Reservoir Storage (TMC)	Lower Reservoir Storage (TMC)	Pumping Capacity (MW)	Cycle Efficiency (%)	Water		Pumping		Discharge			Land Required (In acres)				Forest Clearance Required, If any	Clearances required	No. of families to be dispalced if any	Capex (Rs/MW)	Nearest Evacuation Pouint	Remarks
							Source	Availibility (TMC/Year)	Hours	Energy (MU/day)	Hours	Energy Generation		Govt.	Patta	Forest	Total						
												MU/day	MU/Year										
Kadapa	Gandikota (P1/23-ON-1)	269.87 m	0.178 TMC	26.84 TMC	600 MW	80.05%	Existing Reservoir	As per Lower reservoir capacity	6 Hours 21 minutes	3810 MWh/day	5 Hours 5 Min.	3050 MWh/day	1113.25 GWh/Year	60 Acres	NIL	290 Acres	350 Acres	NO	As per CEA guidelines of PSP projects	Primilary Studies suggests no R&R issues, Detailed study will be conducted at FSR/DPR stage	2.95 Crore per MW	1.Gandikota Power House to 220 kV existing substation at Rayalseema 220kV Substation – Length of each line shall be approx. 27 km. 2.Gandikota Power House to 220 kV existing substation at Gooty – Length of each line shall be approx. 72 km.	All particulars are based on present study and same will be updated at FSR/DPR stage

Appendix - I

INFORMATION GATHERED DURING GANDIKOTA SITE VISIT BY INTER-DISCIPLINARY TEAM FROM WAPCOS

SITE NAME: YEDDULA ESWAR REDDY (GANDIKOTA) RESERVIOR **TALUK:** KONDEYOR **DISTRICT:** KADAPA **DATE:** 03/01/2020

S. No	Details	Remarks
1.	**Project Location**	LOWER RESERVOIR: 0204161, 1638768
2.	**Project Access**	LOWER RESERVOIR IS ACCESSIBLE
3.	**Road Approach to project site (either NH or SH)**	5 KM FROM NH 67
4.	**Nearest Rail Head with Loading or Non - Loading factor**	MANGAPATTINAM (15 KM)
5.	**Nearest Airport**	KADAPA (100 KM)
6.	**Type of Road Network to Transport E&M Components**	NH 67
7.	**How far from NH keeping in view of Transportation of E&M Equipments.**	5 KM FROM NH 67 ABOUT 230KM FROM KRISHNAPATNAM PORT
8.	**Connectivity of Project Components with Road Network**	ONLY LOWER RESERVOIR IS CONNECTED TO EXISTING ROAD
9.	**Accessibility to Upper Dam Area**	THE LOCATION OF UPPER RESERVIOR PROPOSED IN THE DRAWING IS NOT ACEESIBLE BY ROAD.
10.	**Accessibility to Lower Dam Area**	ACEESIBLE BY ROAD
11.	**Broad Idea of HRT and Cover**	POSSIBLE
12.	**Look for Habitation/ Cultivation/ Forest Area/ Any**	PADDY, COTTON, GROUNDNUT, PLANTAIN, ORCHIDS

	Activity/ Type of Land/ Irrigation/ Commercial Activities	
13.	**Habitant Location (Permanent/Temporary)**	TEMPORARY DONTHI KONA
14.	**Any Environmental Reserved Area**	NO
15.	**Nearby Reserved Forest / Sanctuary / National Park (if any)**	NO
16.	**Wild Animal Migration Paths (Seasonal)**	NO
17.	**General - Physical Characteristics of Proposed Reservoir Location**	FOLD TYPE MOUNTAINS AVAILABLE
18.	**Upper Dam Salient Features**	PROPOSED
	- **Existing/ Proposed dam**	
	- **Storage Capacity of Reservoir**	
	- **Live Storage of Reservoir**	
	- **F. R. L**	
	- **Bed Level**	
	- **Length of Dam**	
	- **Height of Dam**	
	- **Area Capacity curve of Reservoir**	
	- **Siltation**	
	- **Discharge Data (Cumecs / suitable)**	
	- **Area of Submergence & Submergence Restrictions**	
	- **Existing Power House (if any)**	
	- **Existing Irrigation Scheme (if any)**	
	- **Main Water Source**	BY PUMPING FROM LOWER RESERVIOR AND MYLAVARAM DAM
	- **Relevant Water Streams**	NO
	- **Perennial / Seasonal**	SEASONAL
19.	**Lower Dam Salient Features**	

	- **Existing/ Proposed dam**	EXISTING
	- **Storage Capacity of Reservoir**	26.84 TMC (GROSS)
	- **Live Storage of Reservoir**	23.72 TMC
	- **F. R. L**	220M
	- **Bed Level**	192M
	- **Length of Dam**	320M
	- **Height of Dam**	25.2M
	- **Area of Submergence & Submergence Restrictions**	109.35 Sq.Km
	- **Existing Power House (if any)**	NO
	- **Existing Irrigation Scheme (if any)**	YES
	- **Main Water Source**	CHITRAVATHI RESERVIOR, OWK RESERVIOR, PENNA RIVER
	- **Perennial / Seasonal**	BOTH
	- **Power Purpose / Multipurpose Dam**	IRRIGATION
	- **Commitment Usage of Irrigation/ Pattern of Crop**	PADDY, PLANTAIN, GROUNDNUT
20.	**Photo with Client Officials**	ENCLOSED
21.	**Photo of Water Conductor Alignment**	ENCLOSED
22.	**Energy Evacuation**	400kV SS (SOLAR) at MYLAVARAM, 132Kv SS at Muddanur & Kondapuram AT ABOUT 25KM, 230kV at Tadipatri SS AT ABOUT 60KM
23.	**Quarry Site Photos (Within 25 km)**	YES
	- **Rock-fill material – Rock Quarry**	ROCK
24.	**Photographs:**	
	- **Interaction with Client Officials**	ENCLOSED
	- **Closure photo of Rock Outcrop**	
	- **Near Project Components**	
	- **Caption of Photos**	
25.	**Relevant Reports of Existing Reservoir Projects**	ENCLOSED
26.	**Cement Production nearby Area of Project Site**	ULTRATECH CEMENTS - 70 KM FROM GANDIKOTA RAMCO CEMENTS - 70 KM FROM GANDIKOTA PENNA CEMENTS - 70 KM FROM GANDIKOTA
27.	**Steel/ Reinforcement Production near Project Site**	GARUDA STEEL PLANT - 70 KM FROM GANDIKOTA

28.	**Proposed/ Planned/ Expected Solar Project in the States/ Project Area**	250MW COMMISSIONED AT MYLAVARAM (UPPER RESERIOR AREA) & WIND ENERGY IS AVAILABLE
29.	**Any Suitable sites of Proposed Solar Parks**	750MW WORK IS ON PROGRESS
30.	**Nearest Sub Station of GENCO (Power Grid Map)**	RAYALASEEMA TPP STAGE-I,II&III (5 X210 MW)
31.	**Alternate Site Location**	AVAILABLE FOR UPPER RESERVIOR
32.	**Interstate Issue**	NO
33.	**Any Other Details**	MYLAVARAM DAM AND GANDIKOTA DAM ARE TWO INTERCONNECTED RESERVIORS, SOLAR & WIND MILLS ARE AVAILABLE VERY CLOSE TO UPPER RESERVIOR AREA, WELL CONNECTED WITH ROADS, 5 BRIDGES ARE TO BE STRENGTHENED, NO WILD LIFE MOMENTS.

GANDIKOTA DAM - LOWER RESERVOIR

Information Board - Sri Yeddula Eswar Reddy (Gandikota) Reservoir

View towards Entrance of Gandikota Dam

Way towards Gandikota Dam – Existing (Lower Reservoir)

View focussing Spillway of Gandikota Dam

Discussing with Client Officials at Site

View towards Conduit – Gandikota Dam – Lower Reservoir

Existing Pump Room – Gandikota Dam – Lower Reservoir

Discussion on Dam Miniature with Client Officials – Gandikota Dam

Way towards Upper Reservoir marked in Map

Existing Tunnel from Srisailam/ OWK Reservoir near to Proposed Upper Reservoir

Existing Tunnel from Srisailam/ OWK Reservoir near to Proposed Upper Reservoir