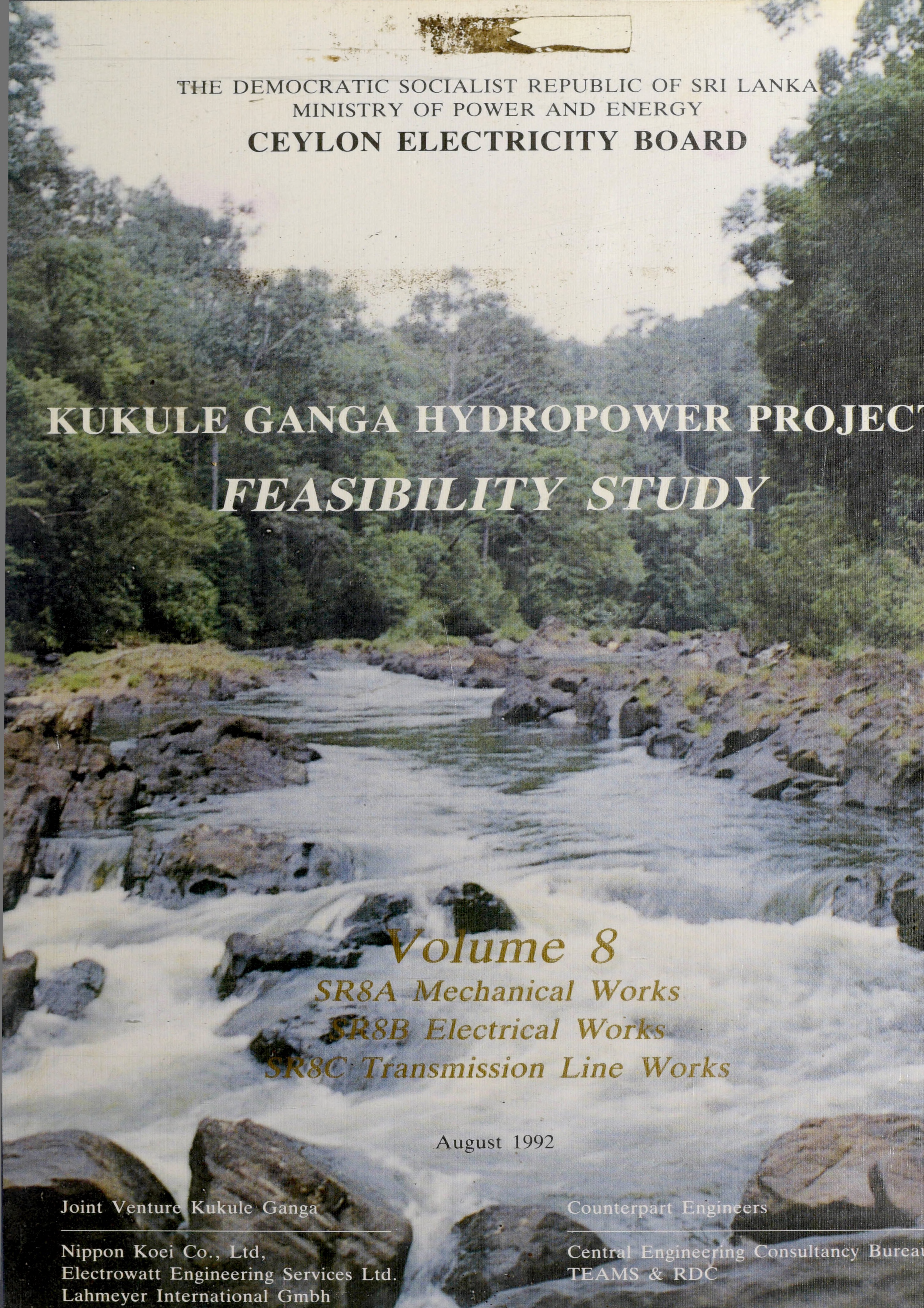

THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA
MINISTRY OF POWER AND ENERGY

CEYLON ELECTRICITY BOARD

KUKULE GANGA HYDROPOWER PROJECT

FEASIBILITY STUDY

Volume 8

SR8A Mechanical Works
SR8B Electrical Works
SR8C Transmission Line Works

August 1992

Joint Venture Kukule Ganga

Nippon Koei Co., Ltd,
Electrowatt Engineering Services Ltd.
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FEASIBILITY STUDY
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FEASIBILITY STUDY REPORT

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SR8A MECHANICAL WORKS

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1. Introduction

The current phase of the feasibility study includes the evaluation of the following three generating plant options:

Option 1:	Alternative plan KK-205-1.5, 2 x 35 MW	=	70 MW
Option 2:	Alternative plan KK-205-2.3, 3 x 35 MW	=	105 MW
Option 3:	Alternative plan KK-205-2.0, 2 x 50 MW	=	100 MW

Based on findings outlined in the Conceptual Design Report, Dec. 1991, option 1 was, to date, the recommended solution for power generation in the near future. It foresees a run-of-river plant with a small head pond for daily peaking during low flow periods.

Peaking capability of the power plant could be enhanced, adding an upstream reservoir and increasing the generating capacity, options 2 & 3. Option 2 considers a staged development, 2 + 1 units = 3 units, while option 3 anticipates installing two units of higher capacity in the initial plant facilities. An economical evaluation conducted during the IIb Phase will provide the conclusive arguments to decide on the most suitable project option by the end of Phase IIb.

It is anticipated that option 1 be carried forward as the basic solution, and the other options be added for evaluation purpose.

2. Hydraulic Turbine

2.1 Plant Characteristics

2.1.1 Number of Generating Units

Lowest equipment cost per kW installed capacity of a hydropower plant, adequately designed for the given plant parameters, will be achieved by the least number of generating units.

It is assumed that two units be the minimum number to yield an availability of at least 50% in case of forced outage or scheduled maintenance. Kukule Ganga shall be operated as a run-of-river plant. A small head pond will allow

Maximum intake water level	204.50 masl
Minimum intake water level	203.50 masl

Tailwater level

- At no generation		16.00 masl
- Option 1,	one unit operation	18.00 masl
	two unit operation	19.50 masl
- Options 2 & 3	max. plant generation	20.50 masl

Head loss (H_l)

- Option 1	$0.00436\ Q^2$
- Option 2	$0.00209\ Q^2$
- Option 3	$0.00209\ Q^2$

Following the format outlined in subsection (1) above, the head data were determined as follows:

Option	1	2	3
Hmax (m)	188.5	188.5	188.5
Hmin (m)	174.1	173.1	173.2
Have (m)	183.7	183.4	183.4

The design head was therefore selected at

H_d (m) = 183.5

for all three options.

2.1.3 Flow

The plant flow was derived from preceding hydraulic investigations for the anticipated three options as follows:

Option	1	2	3
Installed capacity (MW)	70	105.1	100
Net head (m)	174.1	173.1	173.2
Overall efficiency	0.86	0.86	0.86
Plant flow(m3/s)	47.7	68.8	68.5

The installed capacity is referred to the transformer terminals. The overall efficiency considers therefore the entire generating equipment including turbines, generators, transformers and associated auxiliaries.

2.2 Turbine Characteristics

2.2.1 Type

The type of turbine is generally determined by the head and discharge available to generate turbine output. Figure 2-1 reflects the typical operating range for Pelton, Francis and Kaplan turbines. The graph illustrates that the plant parameters are adequate for Francis turbines.

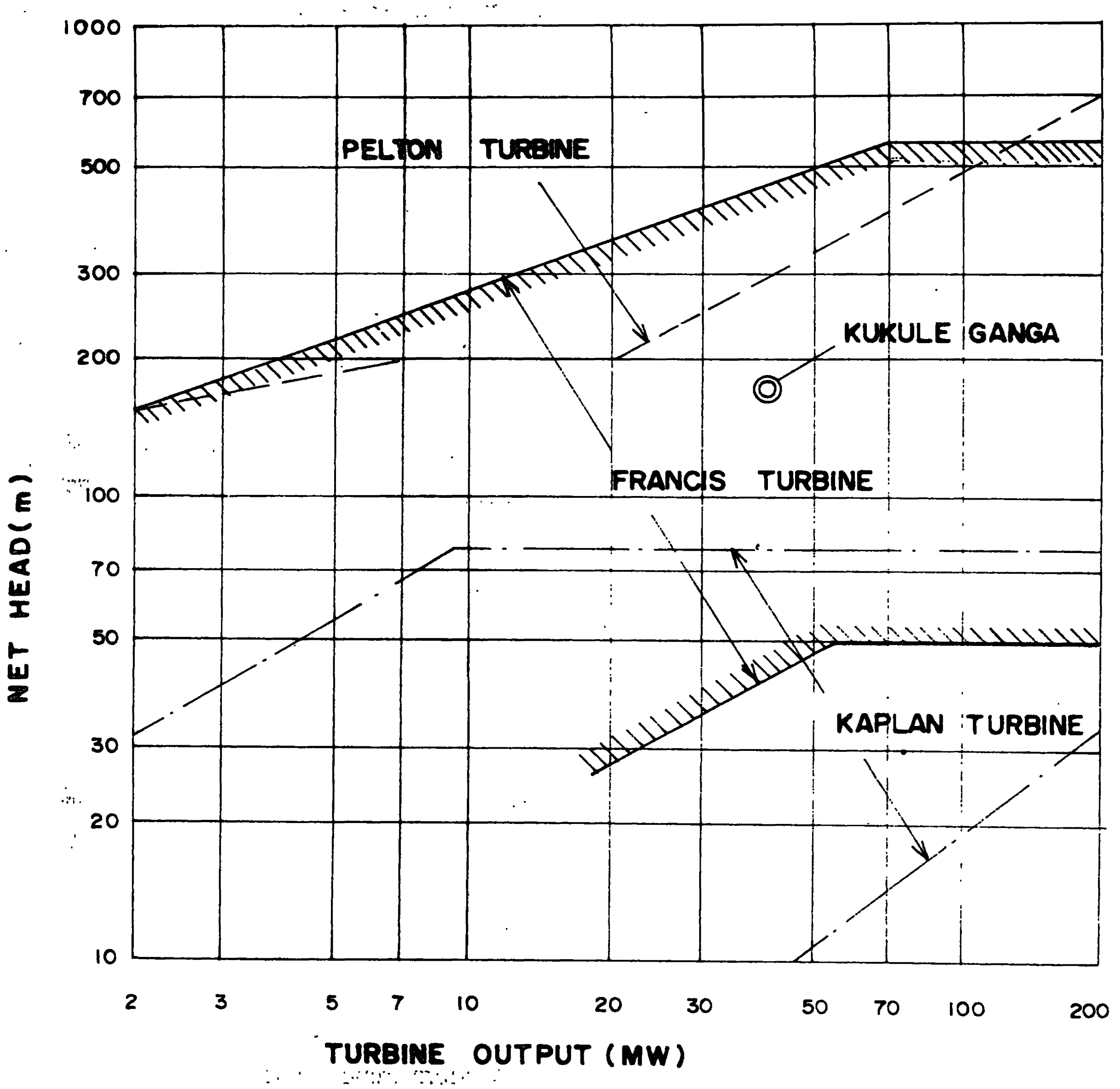
2.2.2 Rated Data

The rated turbine data are derived from the plant parameters listed in paragraph 2.1.5. Rated turbine data are referred to design net head. Flow and output data were converted using the following conversion formulas:

$$Q_2 = Q_1 \sqrt{H_2/H_1}$$

$$P_2 = P_1 (H_2/H_1)^{1.5}$$

Option	1	2	3
No. of units	2	3	2
Design net head (m)	183.5	183.5	183.5
Rated flow (m3/s)	24.49	23.61	35.25
Rated output (kW)	40,000	38,650	57,715
Max. net head at full gate operation (m)	183.9	185.5	183.5
Max. turbine output (kW, one unit operation)	40,130	39,280	57,715



KUKULE GANGA HYDROPOWER PROJECT

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Figure No 2 - 1

Typical Operating range for Pelton, Francis & Kaplan Turbines

2.2.3 Synchronous Speed

The synchronous speed was selected using statistical data given on Figure 2-2, Specific Speed n_s versus Design Net Head H_d, and in Table 2-1. The graph includes Francis turbines designed in 1964-1982.

$$K = n_s \sqrt{H}$$

Specific speed $n_s = n \sqrt{P} / H^{1.25}$

n = synchronous speed (rpm)
P = rated turbine output (kW)
H = design net head (m)

The trend of the statistical data recommends a specific speed at or slightly above K=2000. The selected speed data is therefore as follows:

Option	1&2	3
n (rpm)	500	428.57
n_s	148	152
K	2006	2065

2.2.4 Runaway Speed

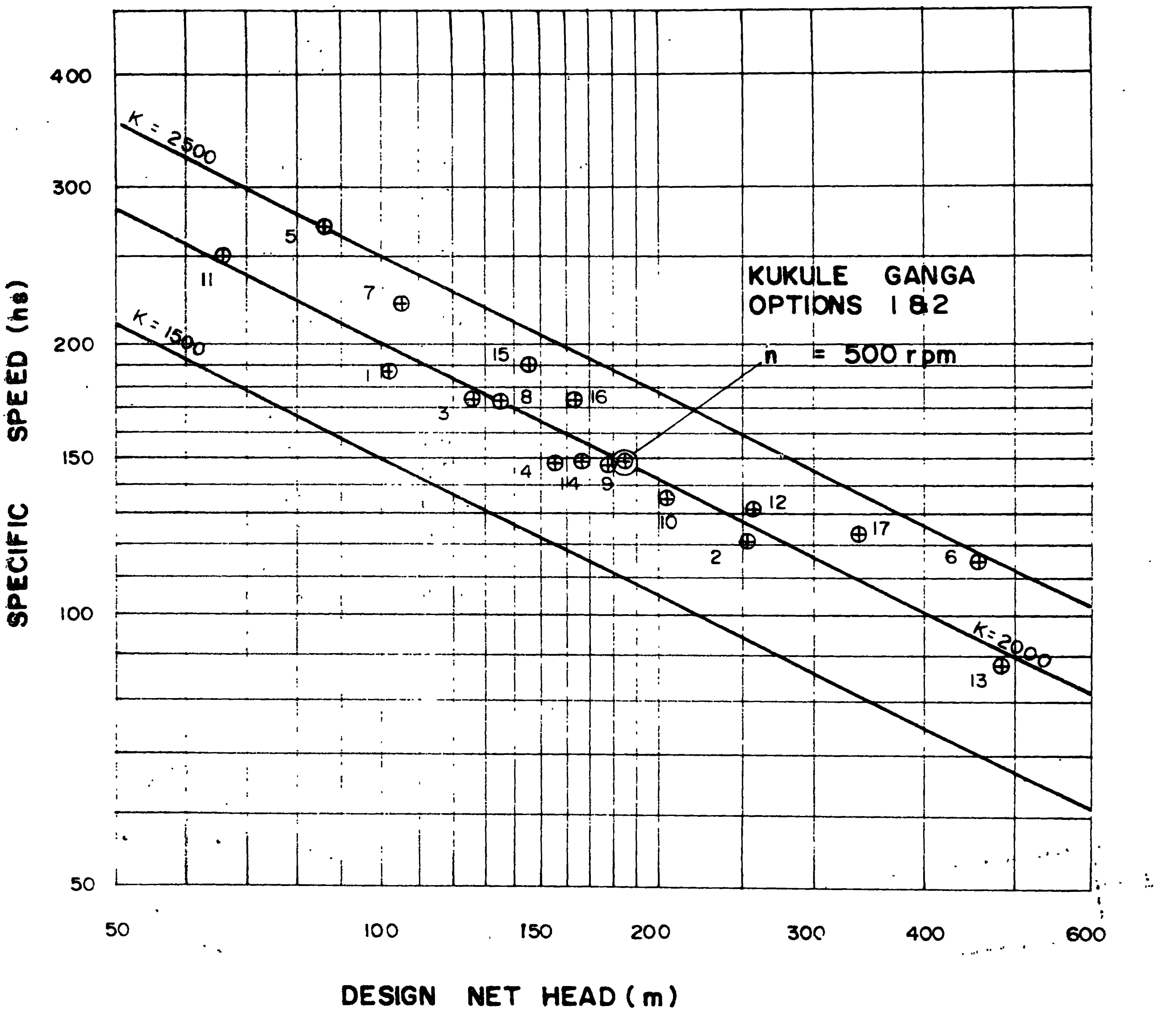
The runaway speed n_f has been estimated

$n_f = 1.85\ n$

using the findings in the article, "Modern trends in selecting and designing Francis turbines", Water Power & Dam Construction, Aug 1976, as a preliminary guide line.

Option	1&2	3
n_f (rpm)	925	800

Runaway speed may be slightly different among turbines of different manufacturers. It will be determined by the selected turbine runner design.



KUKULE GANGA HYDROPOWER PROJECT		Figure No 2-2
Ceylon Electricity Board (IDA)	Joint Venture Kukule Ganga NK, EWI & LI	Specific speed versus Head statistics for Francis Turbines
	CECB. TEAMS	

Table 2.1 Statistics of Typical Francis Turbines

(DataplottedonFigure2.2)

No	Powerplant	Year of Design	Head (m)	Turbine Output (MW)
1	Angostura	1974	100.2	214.0
2	BrommatII	1969	255.0	239.7
3	CaboraBassa	1969	127.0	485.0
4	ElCajon	1982	156.0	75.0
5	GrandCouleeIV	1973	87.0	700.0
6	GrimselII	1974	458.0	106.0
7	HarsprangetV	1974	103.0	469.0
8	Kargamakis	1970	135.0	137.8
9	Langsan	1972	180.0	52.6
10	Mitta	1971	203.0	98.2
11	Mosul1	1981	66.4	155.0
12	Oldan	1972	252.0	68.9
13	Pradella	1964	494.0	75.0
14	RezaShah-Kabir	1970	165.0	278.0
15	Ritsem	1973	145.0	330.0
16	Tumut3	1971	161.5	283.0
17	WaldeckII	1970	336.6	220.0

2.2.5 Turbine Setting

The turbine setting is determined using the Thoma coefficient σ to yield turbine operation without unsuitable cavitation.

$$\sigma = \frac{H_a - H_v - H_s}{H}$$

H_a = Atmospheric pressure (m)

H_v = Vapor pressure (m) at water temp.

H_s = Difference between turbine distributor center line and tailwater elevation as illustrated on Figure 2-3.

The downsurge at the tailrace surge tank, derived from preceding hydraulic investigations, has been taken as the reference tailwater elevation to determine the turbine setting for reliable operation. The turbine setting will be optimized during the tender design phase when the results of a more elaborated hydraulic transients analysis are available. Based on the above, the turbine setting will be as follows:

Option	1	2	3
D/S down surge (masl)	10.7	11.7	11.7
Turbine distributor centre line elevation (masl)	4.5	6.0	5.0

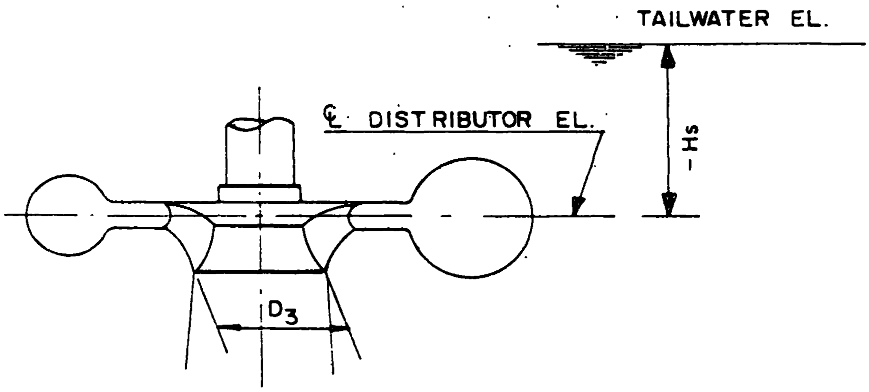
2.2.6 Dimensions

The turbine runner discharge diameter D_3 has been determined using statistical data of specific circumferential velocity K_u versus specific speed ns.

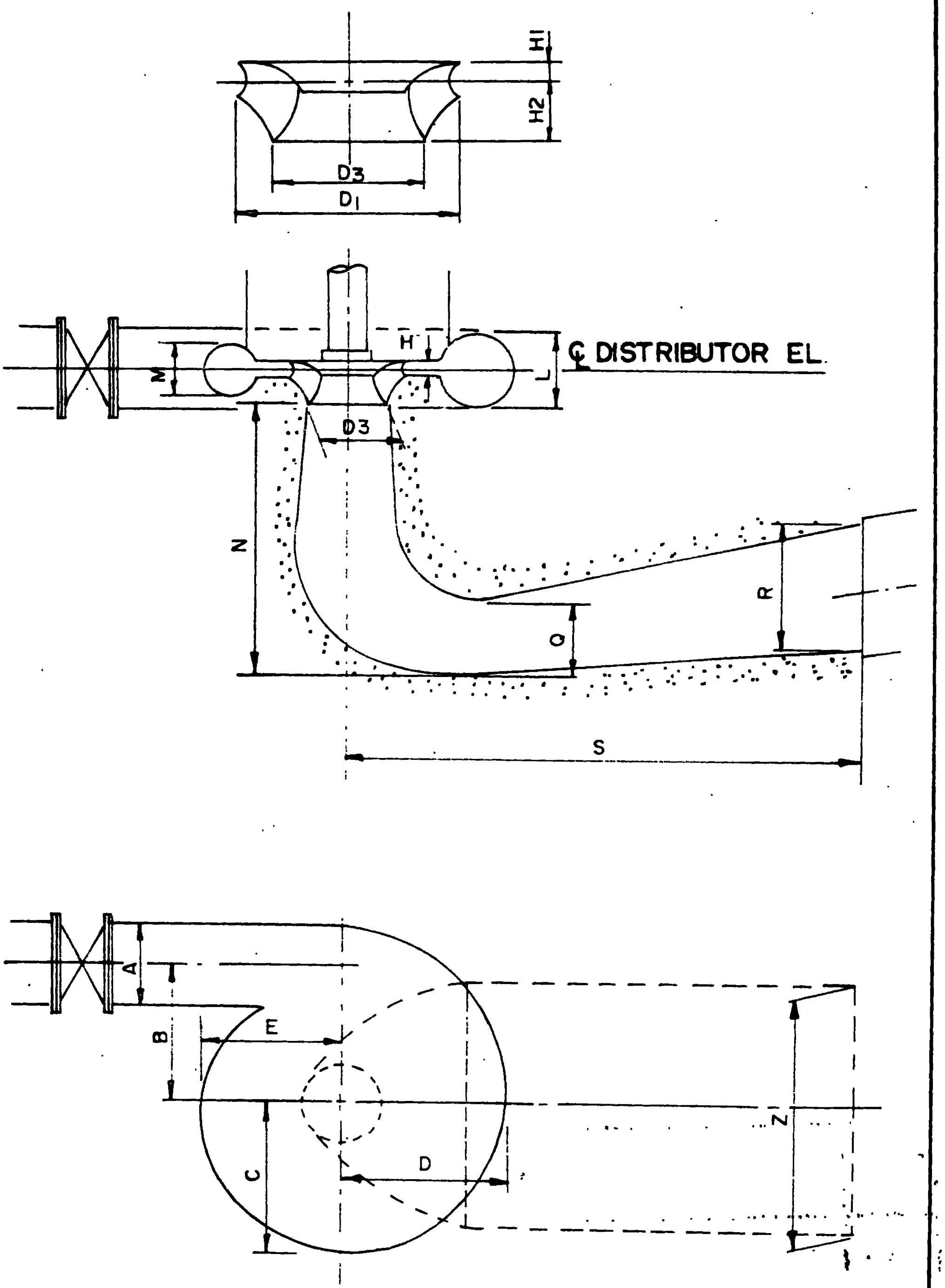
$K_u = f(n_s)$

$D_3 = 84.6\ K_u \sqrt{H} / n$

The remaining turbine dimensions for the powerhouse layout, Figure 2-4 and Table 2-2, were calculated using n_s & D_3 as correlated reference data.



KUKULE GANGA HYDROPOWER PROJECT		Figure No. 2-3
Ceylon Electricity Board (IDA)	Joint Venture Kukule Ganga NK, EWI & LI	**Turbine setting versus Tailwater Elevation**
	CECB, TEAMS	



KUKULE GANGA HYDROPOWER PROJECT		Figure No. 2-4
Ceylon Electricity Board (IDA)	Joint Venture Kukule Ganga NK, EWI & LI	Francis Turbine Dimensions
	CECB, TEAMS	

Table 2.2 Francis Turbine Dimensions (m)

(Data are related to Figure 2.4)

Option 1:	2x35MW	
Option 2:	3x35MW	
Option 3:		2x50MW
Specific Speed (ns)	148.23	152.45
Runner Discharge Dia.(D3)	1.56	1.85
Runner		
D1	1.62	1.88
H1	0.20	0.24
H2	0.53	0.62
Spiral Case		
A	1.67	1.98
B	2.29	2.70
C	2.58	3.04
D	2.85	3.36
E	2.20	2.58
I	0.31	0.37
L	1.49	1.76
M	0.94	1.11
Draft Tube		
N	4.17	4.93
Q	1.30	1.54
R	2.57	3.05
S	7.99	9.46
Z	3.40	4.03

2.2.7 Regulation

The short pressure shaft length between U/S surge tank and turbine inlet provides favorable regulating conditions. The pressure shaft is currently outlined for a concrete lined design. This limits the water velocity at 4.0 m/s and enhances the regulating conditions additionally. The hydropower plant would be capable to cope with the forthcoming regulating requirements that would include speed control at unit start-up and load rejections, and load control at operation in the interconnected system. The configuration of the water conduit system would allow to accept more stringent regulating conditions which could arise in the case of a steel lined pressure tunnel, and therefore a significant diameter reduction, or for operation on an isolated system.

2.2.8 Transients

The results of the hydraulic transients analysis are currently not yet available. Following common practice to outline hydropower projects, the following transient conditions should not be exceeded:

- Pressure rise 30% above max. static head,
- Speed rise 50% above synchronous speed.

2.3 Turbine Design

The units will be of the conventional vertical type including three guide bearings and a thrust bearing. The thrust bearing will be combined with the generator guide bearing above the generator. To ensure an enhanced shaft rigidity, the unit shall be designed without an intermediate shaft between turbine and generator. However, the draft tube cone shall be removable to allow dismantling of runner and turbine shaft toward the draft tube floor. Gate operating ring, head cover and wicket gates can then be disassembled at the turbine floor without affecting the generator.

The turbine spare parts shall include a runner and a set of wicket gates to allow a time effective replacement of defective parts and repair, that implies short turbine downtime. The turbine runner will be an integral stainless steel casting with at least 13 percent chromium and four percent nickel. Spiral case and draft tube liner will be plate steel fabricated. The draft tube shall be steel lined up to the draft tube exit to facilitate the incorporation of the flap gate.

2.4 Turbine Installation

Type and dimensions of the turbine should not represent any significant installation problems. The spiral case shall be embedded in second stage concrete. It is anticipated that the bridge crane be readily installed before the spiral case installation begins.

3. Governor

Each governor will be comprised of the following main parts:

- Digital governor head, located in one of the control panel sections at the machine hall floor.

- Electrohydraulic governor and pressure oil supply system, combined in an actuator cabinet located at the turbine floor.

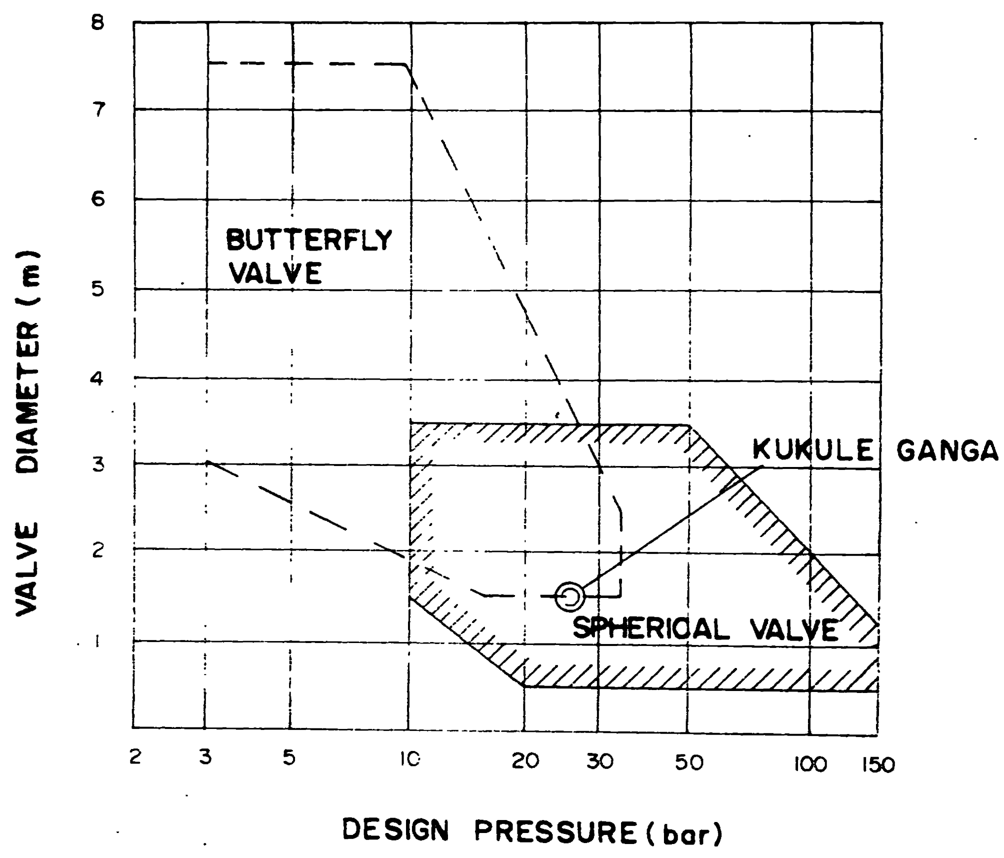
- Pressure oil accumulator located adjacent to the actuator cabinet.

The governor shall be of the proportional-integral-derivative type (PID) to allow optimal setting of the control parameters.

4. Inlet Valve

4.1 Selection of Type

The approximate range of application of spherical valves and butterfly valves is given on Figure 2-5. The Kukule Ganga parameters fit perfectly into the spherical valve range and are at the limit of application of butterfly valves. The butterfly valve would produce a head loss of at least 1.2 m at inflow water velocity of 10.8 m/s, while spherical valves have virtually no head loss. Spherical valves have been reliably operated at a large number of similar hydropower plants and were therefore selected as the adequate type for the turbine inlet valves.



KUKULE GANGA HYDROPOWER PROJECT		Figure No. 2-5 Range of Application of spherical valve and Butterfly valve (Source: Water power and dam construction, Sep'88
Ceylon Electricity Board (IDA)	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS	

4.2 Valve Diameter

The valve diameter shall be equal to or slightly larger than the spiral case inlet diameter to avoid discontinuous flow entering the turbine. Considering the turbine dimensions outlined in paragraph 2.2.6, the spherical valves shall be sized in diameter as follows:

Option	1&2	3
Valve diameter (m)	1.7	2.0

4.3 Mechanical Design

The inlet valves will be normally operated under nearly balanced pressure; a bypass valve will balance the pressure before opening of the inlet valve. However, the valves shall be designed to yield also a safe and reliable operation under exceptional transient conditions. Transient conditions will include pressure transients and valve closing under maximum turbine flow at runaway speed. Stresses under exceptional loads shall not exceed two-thirds of the material yield strength.

The inlet valve will be provided with a downstream service seal and an upstream maintenance seal. An expansion joint will be located downstream of the inlet valve to facilitate alignments and disassembly, and allow that the valve can slide on its supports to compensate axial displacements. It is anticipated that the penstock manifold be rigidly anchored in the surrounding concrete structure to avoid penstock forces acting on the inlet valves. The expansion joint will avoid transferring axial loads onto the spiral case.

The valve will be opened by pressure oil servomotors and closed using weight. The valve shall be equipped with a reliable locking device to provide adequate safety in case of turbine maintenance and overhaul.

5. Draft Tube Gate

Closing the turbine exits against tailrace tunnel shall be accomplished using draft tube flap gates. A typical example of a flap gate incorporated in the draft tube steel liner is shown on Figure 2-6. The gate leaf can be turned in angular direction using pressure oil controlled servo cylinders. The leaf can be locked in open position to avoid inadvertent closing during turbine operation. A bypass valve would allow to fill the draft tube before opening the gate. A flap gate offers the following advantages over a conventional slide gate:

- The integral flap gate arrangement in the turbine draft tube liner allows a simple configuration of the civil structure between powerhouse and downstream surge tank.

- Lateral gate slots are not needed.

- Enhanced operability. A lifting device to operate the gate is not necessary. The flap gate can be operated from a control panel in the powerhouse. The control oil system could be combined with the governor oil system if the oil pressure would suit the required forces.

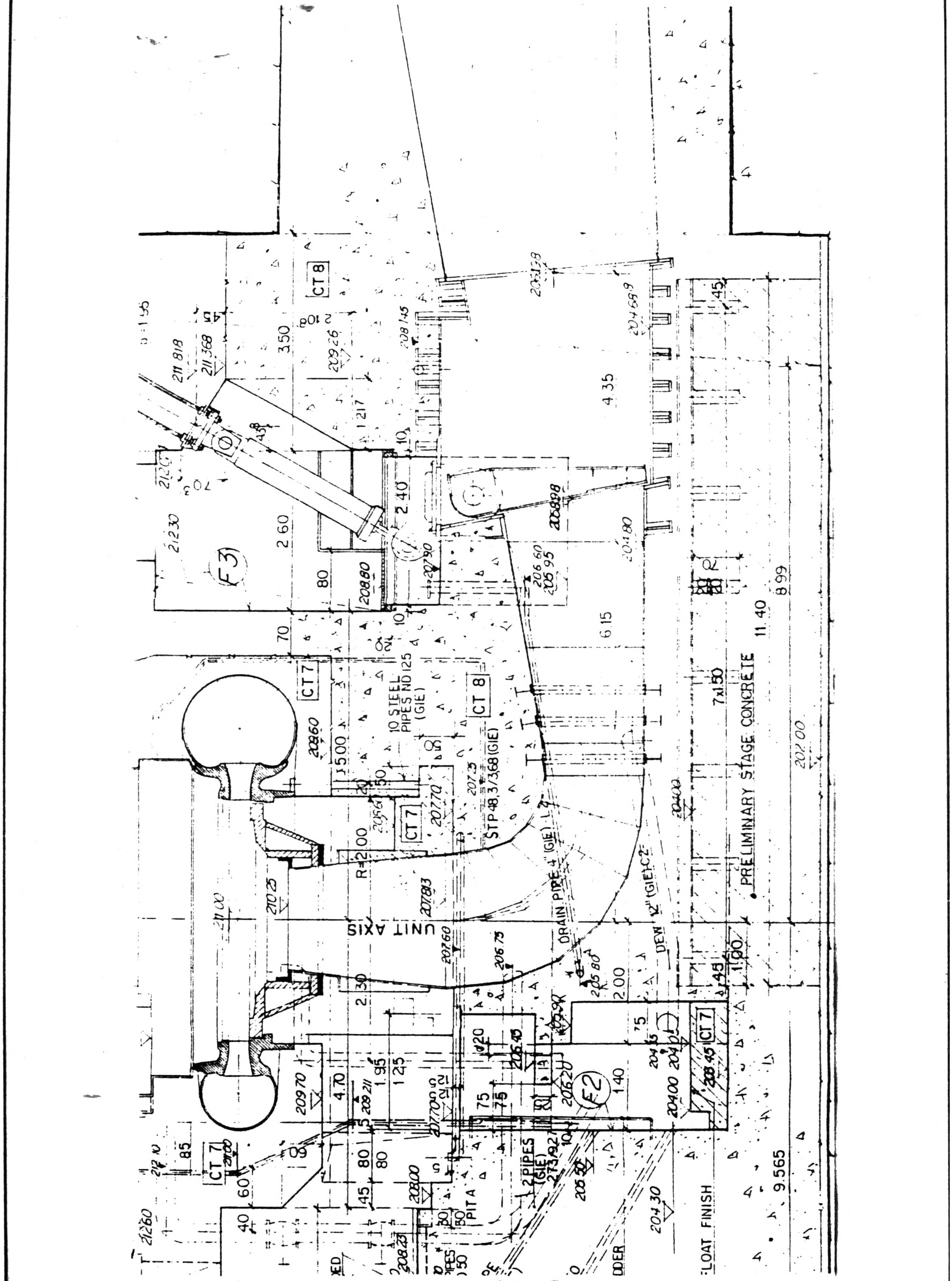
- The flap gate control can be effectively interlocked with the turbine inlet valve control, to prevent untimely closing of the flap gate or opening of the turbine inlet valve.

In underground powerhouse arrangements, draft tube flap gates were installed and have been successfully operated in several cases to simplify the structural configuration and enhance the operability of the units. Draft tube flap gates were, for instance, installed in the following hydro plants:

- Gagnano,	Italy,	2 x 67.7	MW,	435 m head
- Coo-Trois Ponts,	Belgium,	6 x 134	MW,	259 m head
- Ova Spin,	Switzerland,	2 x 34	MW,	200 m head
- Turlough Hill,	Ireland,	4 x 72.5	MW,	282 m head
- Agus IV,	Philippines,	3 x 52	MW,	106 m head
- Mosul 3,	Iraq,	2 x 112.5	MW,	325 m head

6. Dewatering & Drainage Systems

Dewatering and powerhouse drainage will be accomplished using two separate pumping systems.



KUKULE GANGA HYDROPOWER PROJECT		Figure No. 2-6
Ceylon Electricity Board (IDA)	Joint Venture Kukule Ganga NK, EWI & LI	**Typical example of a Flap Gate at Turbine Draft Tube**
	CECB, TEAMS	

(1) The following facilities will have to be occasionally dewatered:

- Headrace tunnel, upstream surge tank and pressure shaft.
- Turbine spiral cases and draft tubes.
- Downstream surge tank and tailrace tunnel.

The upstream water will be generated through the turbine until a minimal acceptable water level is reached. The remaining water will be discharged into the draft tube.

The spiral case water will be discharged into the draft tube.

The draft tube water and, on rare occasions, the tailrace water will be pumped to the downstream using dewatering pumps located in a pressurized sump.

(2) The drainage system will be comprised of drainage pumps and associated auxiliaries located in a collector sump. The drainage sump will be located below the bottom floor, and be designed to achieve minimal rock excavation. An auxiliary drainage system will drain the low leveled dewatering gallery into the main drainage sump.

7. Raw & Filtered Water Systems

The raw and filtered water systems will include the following subsystems:
- Raw water & fire fighting water system.
- Cooling water & shaft seal water system.
- Potable water system.

Raw water will be taken from the tailrace and pumped to the consumers as needed. Strainers and filters will treat the water as necessary. The cooling water system will mainly serve the following consumers:
- Generators.
- Generator and turbine bearings.
- HVAC system.

Owing to the run-of-river character of the hydropower project, it could be necessary to outline the cooling water system in a two loop arrangement with intermediate heat exchangers to keep generating components free from sediment loaded water and facilitate regular cleaning without interruption of the generation. The adequate concept will be developed at tender design.

The fire fighting water system will be combined with a static reservoir with correlated booster pumps to provide safe storage for emergency cases. The reservoir shall be integrated in the cable shaft or test adit arrangement.

8. Compressed Air Systems

High pressure air shall be provided to charge the pressure oil accumulators of governors and inlet valve control units. Low pressure air is needed for the generator brakes and station supply. Each system will consist of two compressors and an air storage tank. The systems will be controlled to provide automatic lead-lag operation of the compressors.

9. Bridge Crane

One overhead bridge crane will be installed in the powerhouse cavern to handle equipment as needed for installation and overhaul of the generating units. The main hoist capacity is determined by the heaviest erection weight, the generator rotor. The powerhouse has been outlined to obtain a relatively narrow span, although the inlet valves are still within reach of the main hook. For the potential project options, the following lifting capacity and span are needed:

Option	1&2	3
Main hoist lifting capacity (kN)	1,000	1,400
Span (m)	11	13

10. Elevator

Considering that the powerhouse dimensions allow a convenient access to all electromechanical facilities, and that the units will be remotely controlled from the control room in the service building it is not anticipated to install an elevator in the cavern. Transportation of medium sized loads can be achieved using the auxiliary hoist of the bridge crane.

11. Workshop Equipment

A workshop shall be provided at the machine hall floor near the assembly area. It will be furnished with standard and special tools, work benches and tools machines to warrant regular maintenance and repair works. It is not recommended to arrange a welding booth in the cavern, but in the vicinity of the access tunnel entrance to reduce forced ventilation for smoke removal.

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SR8B Electrical Works

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SR8B ELECTRICAL WORKS

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CHAPTER I. GENERAL

1.1 Main Components

The electrical equipment required for the Kukule Ganga Hydropower Project comprises the following main components which are described in detail in the subsequent sections.

- Electrical equipment in the power house
- Unit-transformers
- 132 kV-switchyard
- 132 kV-transmission line to the grid substation at Matugama
- 132 kV equipment for the extension of the Matugama substation
- 33 kV-transmission line to the diversion weir site
- Telecommunication system for the Kukule power plant

1.2 Design Standards and Basic Data

The layout and design of the electrical equipment to be installed in the Kukule power plant will be based on the following standards and basic data.

- Standard I.E.C.

Service voltages under site conditions:

Generation	13.8 kV ±5%
Transmission	132 kV
Sub-transmission	33 kV
Auxiliary Services	400/231 V-AC
	125 V-DC
Rated Frequency	50 Hz
Neutral of Generator	Grounded through protective reactance

Insulation Level

The site conditions do not require any special measures with respect to the insulation level because the elevations of the power house and its other facilities do not exceed 1,000 m above sea level. The tropical climate and the high humidity require anti-fog type insulators for the open air installation.

1.3 Restrictions for Transportation

For the transportation of the electrical equipment practically no restrictions are to be expected, taking into consideration that stator and rotor can be divided into several parts for transportation to reduce the dimensions and weight.

These possibilities will have to be considered for the design of the following components:

- Unit transformers 132/13.8 kV
- Generator rotor
- Generator stator

The dimensions of these parts and their transportation weight will have to be checked carefully during the final design stage together with local authorities for the entire route of transportation to make sure that all bottlenecks can be passed without problems; e.g. bridges, narrow roads in villages.

Furthermore, the availability of the corresponding handling and transportation facilities, i.e. cranes, trucks and trailers of respective capacities has to be verified during that stage.

1.4 Electrical Equipment in the Powerhouse

1.4.1 Generators and Accessories

The generators will have an upper combined thrust and guide bearing and a lower guide bearing which corresponds to type W 41. The rotor itself will probably be of the laminated rim tape. The stator can be subdivided into two parts for transportation. The cooling will be effected by a closed circuit system with heat exchangers, cooling the circulating air with water from the river.

The main technical data of the generators will be:

	a) Option I and II	b)	Option III
- Rated output	46 MVA	-	66 MVA
- Rated voltage	13.8 kV±5%	-	13.8 kV±5%
- Power factor	0.85	-	0.85
- Rated frequency	50 Hz	-	50 Hz
- Rated speed	500 rpm	-	428.57 rpm
- Nominal runaway speed	925 rpm	-	792 rpm
- Flywheel effect	520 tm^2	-	1,100 tm^2(approx.)
- Torque moment	90 mt	-	150 mt
at 3-phase short cir.	500 tm	-	830 tm (approx.)
at 2-phase short cir.	650 tm	-	1,080 tm (approx.)

Approximate dimensions and weights:

- Inner diameter of stator	2.92 m	-	3.57 m
- Outer diameter of stator	4.86 m	-	5.76 m
- Depth of generator pit	1.95 m	-	2.56 m
- Weight of complete rotor	103 t		146 t (approx)
- Weight of complete generator	150 t		210 t

For reasons of quick exciter response static exciter equipment shall be installed. This equipment has proven in the past its functional reliability.

1.4.2 Medium Voltage Equipment in the Powerhouse

The medium voltage equipment in the powerhouse cavern comprises:

- the 13.8 kV - cubicles for the circuit-breaker of the generator and its neutral.
- the bus-ducts between the terminal of the generator and the circuit-breaker.
- the bus-ducts between this circuit-breaker and the bushings of the unit transformer as well as to the terminals of the auxiliary and excitation transformer.

- the interconnection in form of bus-ducts between the terminals of the neutral of the generator and its corresponding cubicle for the installation of potential transformers and earthing transformer required for the protection of the stator.

<u>13.8 kV - equipment for the generators and auxiliary including the main connections between generator and 13.8 kV switchgear</u>

Based on a rough calculation and on preliminary data for the equipment of the Kukule Project, the 13.8 kV equipment will have to withstand an initial short-circuit of approximately 785 MVA, if units of 46 MVA would be installed which corresponds to a maximum short-circuit current of approximately 110 kA at peak, and a three pole short-circuit current of approximately 40 kA. These values will increase in 3 units, each one 46 MVA to 920 MVA, I_s - 123 kA (peak) and I_k" = 48 kA. In the case of 2 units with 132 MVA together s_k" = 1064 MVA I_s = 142 kA (peak) and I_k" = 56 kA. The 13.8 kV switchgear will be metal clad draw-out type in which the circuit-beaker of the generator current-transformers, potential transformer, lightning arresters will be installed. The circuit breaker is operated by a DC-motor. It is planned to erect it in a separate gallery on the same level as the generator floor. Each generator is equipped with its own circuit-breaker as shown in the single line diagram, Drawing No. 23 in Volume 2.

1.4.3 Busbar Ducts

The busbars are fully phase insulated and capacitor controlled. The insulation is in direct contact with the bar or tube conductors, with capacitive control provided by conducting layers at its end. The covering layer at earth potential is fully embedded in the insulation.

The bars are connected to the apparatus rigidly or flexibly, using screw or plug type joints. Standard supporting structures and clamps are able to withstand the short-circuit forces, if any.

1.4.4 Auxiliary Transformers

As it can be seen on the single line diagram, Drawing No. 23 in Volume 2, each unit is equipped with its own auxiliary transformer so that the drives, motors and all other apparatus belonging to this unit are fed in by this transformer to have the two units independent to each other.

The capacity of each transformer will be 750 kVA. These will be connected directly to the above-mentioned bus-duct. The transformers are dry-type (cast-resin transformers). Core and windings are not contained in an insulating liquid. The heat losses are dissipated directly to the ambient air, hence the transformers shall have a large surface area and low current density. Accordingly these transformers can be installed in any place without requiring special measures.

The transformer will have the following nominal data and characteristics.

-	Rated power	750 kVA
-	Rated voltage high voltage winding	13.8 kV
-	Rated voltage of the low voltage side	400/231 V
-	Tap changers: on the high voltage side, off-load2	2 x ±2.5%
-	Winding connection	Dy5
-	Impedance voltage	6%
-	cooling	nature air cooled (AN)

These transformers are equipped with an over temperature protection, having 2 steps; one for warning and the other one for tripping.

1.4.5 Low Voltage Equipment in the Powerhouse

Each unit will be equipped with its own and independent low-voltage panel, installed in the electrical gallery close to its corresponding unit auxiliary transformer. It is equipped with two incoming feeders, which are interlocked mutually, and all the outgoing feeders for the turbine generator unit.

This panel is equipped with draw-out units, and is divided into equipment compartment, busbar compartment and cable compartment. To ensure the requisite arc resistance, partitions are essential between the equipment and busbar compartments.

1.5 Additional Equipment in the Powerhouse Area

1.5.1 Electric Power System

In addition to the illumination there will also be an electric system in the powerhouse area. It will be a three phase installation with four conductors for 400 V with power plug sockets on all floors to which electrical tools, welding transformers for repair and maintenance can be connected. This electric power system will be supplied from the low voltage panel provided for the common auxiliaries.

1.5.2 Telephone and Staff-locater System

The telephone system should be completely automatic allowing direct dialling. Direct connection with the public telephone system of the region is not envisaged. The installation should provide for 40 internal connections and 2 external lines for the connection to the carrier frequency system.

A staff-locater system should be installed covering mainly the cavern and the 132 kV switchyard to allow the direct calling of a limited number of persons.

1.5.3 Fire Fighting Equipment for Generators

The installation consists of a gallery for gas cylinders, a system of pipes and valves inside the generator pit. The gas content in the cylinders can be checked and monitored by means of balances, which give an alarm as soon as any gas losses are detected.

1.5.4 Emergency Diesel

Although each unit has its own auxiliary transformer which supplies power to the LV panels of the turbines as well as to the LV panel for the common users of the powerhouse, it is recommendable that an emergency diesel generator set be installed for the supply of the most important auxiliaries such as air-condition, illumination and so on during a complete blackout of the plant, although a backup power supply is available via the 33 kV system through the double circuit 132 kV transmission line.

The features of this emergency diesel are as shown below:

- Rated output	750 kVA
- Rated voltage	400/231 V±5%
- Nominal power factor	0.8
- Rated frequency	50 Hz
- Rated speed	1,500 rpm

The excitation and voltage regulation will be of the automatic self-regulating type. This emergency set will not be installed in the cavern.

1.5.5 13.8/132 - Unit Transformers

This will be a three-phase oil immersed transformer, located on the down-stream side of the cavern in boxes near the units on the level of the machine-hall floor. It will be equipped with an on load tap-changer as well as with all the protection devices required for this type and size of power transformer and comply with the JEC-76 standard.

Main Data	Option I & II	Option III
- Rated output	46 MVA	66 MVA
- Rated low voltage	13.8 kV	13.8 kV
- Rated high voltage	132 kV	132 kV
- On-load tap-changer	±16% in±9 steps	±16%in±9 steps
- Connection group	Yd5	
- Impedance voltage	11%	
- Shipping weight	65 ton	75 ton

The cooling method will be ONAF1, which means oil natural circulation air forced circulation.

The bus-links on the 132 kV side are executed like SF_6-filled pot-heads for the outgoing 132 kV cables.

The above-mentioned values for rated high voltage and the percentage for tapping are preliminary. The final values will have to be determined during the elaboration of the final design, taking into consideration the real values of the transmission line.

1.5.6 Fire Extinguishing Equipment

For the protection of the unit transformers a so called "sprinkler-system" will be installed.

The water acts as a cooling agent so that the temperature in the burning material does not remain high enough to sustain combustion. With the high pressure water jet system, the oil surface is bombarded, thus forming an unstable mixture of oil and water. At the same time the cold water cools the oil so that the vapourization rate is reduced.

Water spray or mist also cools the oil and in addition uses the water's latent heat of evaporation for cooling. The water vapour also dilutes the air and reduces the oxygen feeding the fire. With the use of water there is no danger of re-ignition. For the generators water cannot be used, because it will create corrosion in the stator and poles and can enter into the bearing.

1.6 Inter Connection Between 132/13.8 kV-Transformers and the 132 kV-Switchyard

The space requirements in the cavern will not favour its installation in the power house.

Nevertheless, if it is installed in the powerhouse, a distance between the unit-transformers and the pot-heads of the transmission line will be long.

If these cables are placed in the access tunnel, the length of each cable will be about 950 m. It is recommended that an inclined shaft be provided from the top of the transformer boxes directly to the 132 kV outdoor switchyard. In this way the distance between the two places will be shortened to about 350 m, which is an advantage as far as the costs of the 132 kV cable are concerned. In the attached cost estimation this difference is shown.

1.6.1 132 kV Switchyard (outdoor)

Its final design will depend on the number of units, two or three, and if there will be only one outgoing transmission line or two.

1.6.2 132 kV Equipment

According to preliminary calculations the short-circuit level at 132 kV will be supposed to be not higher than 2,500 MVA. For the final design the short-circuit power provided by the 132 kV network and its foreseeable increase has to be taken into consideration.

The rated values for the 132 kV equipment will be:

- Rated voltage	132 kV
- Maximum operating voltage	145 kV
- Rated current for instrument transformers	400/1/1/1 A
- Rated tension for p.t.	$\frac{132}{\sqrt{3}} / \frac{0.110}{\sqrt{3}} / \frac{0.110}{\sqrt{3}}$ kV
- Rated current for circuit breakers and disconnectors	400 A

1.6.3 Auxiliaries Services - Service Building

The auxiliary services necessary for the proper functioning of the 132 kV equipment shall be housed in a service building, located close to the switchyard. The main components will be:

- Protection panels for the switchyard as well as for the outgoing transmission line
- Low voltage panel for the power supply of the service building and for the power supply of the cavern in case of emergency
- D.C. panel with batteries for the power supply of the circuit - breakers and disconnecting switches
- Control panel for 33 kV switchgear for power supply to the intake area.
- Control panel for remote-control of the turbine-generator units.

1.7 Additional Services

In this section such additional services are described briefly which are necessary for the proper functioning of the power plant as a whole and which have not yet been mentioned elsewhere.

This equipment comprises:

- Electrical installation required in the intake area
- 33 kV transmission line to the intake area
- Electrical facilities for the power supply of a housing area and construction camp.

Due to the lack of information, only the following can be suggested at this stage:

- 4 feeders with circuit-breakers and equipment necessary for 33 kV overhead lines or cable routes.

Any further equipment required must be determined during the final design.

1.8 Electrical Equipment for the Water Intake Area

This area should be fed in through a 33 kV overhead line. Therefore, it is needed to provide a 33 kV incoming feeder.

- One oil-immersed three-phase transformer
- One low voltage panel for the supply of all electrical apparatus being necessary for the proper function of this area.

The three-phase outgoing feeders will be equipped with fuses and contactors where required, or with fuse disconnectors.

The single phase outgoing feeders will be equipped with miniature-automatic circuit-breakers. The number and rating of the outgoing feeders will be determined during the final design stage of the project.

- One D.C. distribution board with rectifier and battery .
- One diesel-generator for emergency supply with a capacity of 150 kVA
- One carrier frequency equipment for data transmission and communication to the control room.

CHAPTER II. GENERAL REMARKS AND/OR DEVIATIONS FROM THE CONCEPTUAL DESIGN REPORT

2.1 Description of Single Line Diagram

Provided that the 132 kV transmission line is energized, the 132 kV circuit-breaker of the line itself as well as the 132 kV circuit-breaker of the unit can be closed. Via the auxiliary transformer for the LV panel of the corresponding unit (1BFT01-2BFT01) by closing the LV circuit-breaker of this panel, all the auxiliaries of the turbine can be commissioned. All the remaining facilities can be supplied through the interconnection between the turbine-panel (1BFA or 2BFA) and the LV panel for the general purpose (0BFA). As soon as the turbine has been started and reached the correct speed and voltage, it can be synchronized by means of the circuit-breaker between the unit transformer and the generator (1BAC, 2BAC). A synchronization on the 132 kV is also possible.

Second way to start-up the plant, when the transmission line is energized, is via the auxiliary transformer (0ACT01-0BFB) which feeds the panel for general purposes. In this way all the facilities of the cavern can be energized. By closing the interconnection between this panel and any LV panel of a turbine, the auxiliaries of the turbine can be put into operation and the unit can be started. The unit can be synchronized with the 13.8 kV circuit-breaker as soon as the 132 kV circuit-breaker is closed or vice versa. The turbine will deliver all electrical power for the power house and the auxiliary transformer will be switched off.

If the generator should trip at any mechanical or electrical fault, the 13.8 kV circuit-breaker opens. The auxiliaries of the turbine and the powerhouse, however, continue to work without any interruption. If the unit trips due to a fault in the unit-transformer, the power supply will be maintained either by the other unit or through the transformer for local supply (0ACT01). These operations will be controlled automatically.

A third way to start the plant, when the transmission is not energized, can be realized by operating the emergency diesel, black-start. In this case the diesel takes the function of the auxiliary transformer and the procedure is in principle similar to the second possibility; emergency diesel, busbar 0BFC, panel 0BFB.

2.2 Localization of Equipment

2.2.1 Power House/Transformers

For the localization of the unit transformers various considerations were made.

First of all all the unit transformers are to be installed on the level of the machine hall floor. The reasons leading to this decision were the following:

a) Easy transport of the transformers to their corresponding box.

b) Easy access to the transformers even when the units are running, so that inspections can be done at any time without interruption of the corresponding unit operation, less complicated maintenance, checking of oil leakage or change of oil if necessary.

c) Higher protection against external influences.

d) The ventilation of the transformer boxes can be realized much more simply by installation of ventilation channels on top of the boxes.

e) Higher efficiency of the fire fighting system.

f) More space will be available in the box for erection of the transformer which will be shipped without bushings, radiators and oil.

g) Last but not least, simple installation of the outgoing 132 kV cables, which will be installed also on top of the boxes.

The width of the transformers is approximately 3.5 m and requires a width of the box of about 5 m. This allows a walkway width of 0.75 m each on both sides, which meet the standard requirements for security. The width of the transformers requires a minimum clearance between wall of the transformer boxes and the outer cover of the generators.

Each transformer can be moved by means of the powerhouse crane to its individual box, in front of which a temporary supporting device has to be installed in order to draw the transformer in its definite position by means of a winch.

2.2.2 SF6 - Switchgear

In the conceptual design report an installation of this switchgear inside the cavern was suggested. This is possible in principle but according to the prevailing standards a separate and closed room is necessary for this kind of equipment. The minimum depth required for the installation of this switchgear will be 7.5 m. This dimension will disturb the straight front view formed by the transformer chambers since switchgear has to be located adjacent to the last transformer box.

In the room for the SF_6 switchgear a crane has to be installed, having a capacity suitable for the heaviest components.

SF_6 installations must also include provision for disposal in the event of leakage or defects. According to VDE data sheet, natural ventilation is sufficient for equipment rooms aboveground. provided 50% of the air cross - section is close to floor level. Being installed underground, forced-flow ventilation is necessary as SF_6 gas can accumulate in dangerous quantities. The ventilation system must entrain SF_6 laden at floor level.

Rooms situated below such installations and in connection with them must also be well ventilated or be included in the ventilation system.

Another important point is the cost for this kind of equipment which is generally twice higher than an outdoor equipment, and as appearing on a later page, an outdoor switchyard should be taken into consideration.

2.2.3 Unit Control Panels

Each unit will have its own and independent control panel installed on the machine hall floor. The components and/or elements which will be installed in it are mainly:

- unit protection system
- turbine governor
- instruments, signalling system, switches and push-buttons for local operation of the unit.

Close to this unit control panel will be installed a so called "remote input-output panel" necessary for the remote control and transfer of all informations and instructions to the control building to be located outside the cavern (Service Building at switchyard).

A localization of this equipment close to each unit in the center of the machine hall floor seems not recommendable. Being equipped with sensitive and important elements, the unit-control panels with their corresponding interfaces should be located in a separate cabin, adjacent to last transformer box maintaining the same line as in the boxes.

2.2.4 Medium and Low Voltages Equipment

On the generator floor level all the electrical facilities required for each unit will be installed. These facilities consist of:

- 13.8 kV generator circuit-breaker (2 cubicles)
- neutral point of the generator (1 cubicle)
- excitation transformer
- excitation system
- low voltage panel for the power supply of all auxiliary drives for turbine and generator
- One auxiliary transformer for the power supply of the above-mentioned low voltage panel.

The equipment above will be installed for each unit to be independent to each other.

For the power supply of common consumers such as crane, air-condition, fire fighting, pumps, illumination etc., a separate low voltage panel will be installed on the same level. Also the battery will be installed on this level as well as the CO_2 - fire protection equipment for the generators.

The interconnection between the terminals of the generator and circuit-breaker of the generator as well as the connection between the circuit-breaker and the terminals of the unit-transformer and auxiliary transformers will be realized by means of fully phase-insulated, capacitor-controlled busbars.

2.3 Additional Services and/or Installations

The intake and spillway gates at the diversion weir site require electricity supply for its operation. This power will be supplied from the Kukule power plant. The distance between the outdoor switchyard beside the powerhouse cavern and the diversion weir site is about 5 km. For this distance a transmission voltage of 6 kV would be sufficient. However, to adapt to one of the standard voltages used by CEB as well as to connect this line to the existing 33 kV line in the region, the voltage of the transmission line from the switchyard to the weir site is selected to be 33 kV.

This transmission line may be used also for the transfer of data between both places by means of a carrier frequency system. An outdoor transformer of 132/33 kV (0ACT01) should be installed, so that this 33 kV line can be energized via the 132 kV line and can supply energy to the intake area.

For the other consumers in the vicinity such as construction camp and/or housing area, the same 33 kV line can be used. During the erection period, no temporary power supply system like diesel would be necessary but these demands can be supplied by constructing a 33 kV line branching off the existing 33 kV line running near the Mipagama Bridge.

Having 33/0.4 kV transformer the line can supply energy to the service building of the substation and to the cavern, which can be used also for the erection works to be done in cavern, so that in the cavern too no temporary generating units are required. Another advantage of the implementation of this transformer is the possibility to serve as 'a third leg' for the cavern. Normally the entire powerhouse and its consumers are supplied via the unit transformers and the corresponding auxiliary transformers; feeding in this way the auxiliaries of the units as well as the common consumers such as pumps, lighting, compressed air, air-condition etc. The busbar for the common consumers is a separate system which will be fed in either by unit 1 or unit 2 or transformer 0ACT01.

If, however, by any reasons the unit transformers are not available, the common consumers remain without energy. In this case the 'third leg' can resolve this shortage by feeding in this busbar for the common consumers, and allows to execute tests also for the auxiliaries of each turbine, if desired.

It is recommended that an emergency diesel be installed in the outdoor switchyard. No additional cavern is necessary and there will be no problems in its exhaust gases. Maintenance can be done aboveground to keep it in a good condition for the start in case of emergency. Having a 132/33 kV transformer and a 33/0.4 kV transformer and an emergency diesel outside the cavern, in case of an inundation of the cavern, electricity is still available for the drainage pumps and even in the worst case of two failures occurring concurrently; blackout in the 132 kV network and an inundation of the powerhouse. Installation of the emergency diesel in the outdoor switchyard or its vicinity is recommended.

2.4 132 kV - Equipment

The localization of the 132 kV equipment turns out to be an important issue.

When a SF_6 - switchgear is installed inside the cavern as shown in Figure 5, there will be no power supply readily available for the service building and the intake. Consequently a transformer of 132/33 kV with a 33 kV switchgear has to be installed additionally with its own transformer box and oil sump. Also required are another transformer of 33/0.4 kV, and a corresponding low voltage panel, to cover the LV power demand of the service building. From this switchyard 33 kV busbar there shall be outgoing feeders to the intake and other facilities such as housing area, construction camp and so on. The diesel can be installed in the vicinity of the service building.

The same procedure was done for an outdoor installation of the 132 kV equipment. Besides the economic viewpoint, the technical aspects are to be taken into consideration.

2.5 Reliability of Power Supply to the Cavern

To ensure a power supply to the cavern in case of emergency, let's say with emergency supply, from the attached scheme it can be learnt that various components are necessary.to get this emergency supply onto the terminals of the low voltage panel which shall supply the common consumers such as air-condition, lighting etc.

The following components must be available:

- low voltage panel in the service building — 0BFC
- transformer 33/0.4 kV — 0BFT01
- the 33 kV switchgear in the service building — 0ACA
- the cable interconnection onto the 33/132 kV transformer in the cavern (0BAC01)
- the SF_6 switchgear — AEA/AEB
- at least one unit transformer — 1BAT01 or 2BAT01
- the corresponding auxiliary transformer — 1BFT01 or 2BFT01
- the corresponding LV panel of the unit

It is evident that the reliability of this circuit is less than that of the second version as it can be learnt from the attached sketch.

In case of emergency this circuit is like a bypass and its availability depends on:

- the low voltage panel in the service building, 0BFC
- the cable interconnection between this low voltage panel and the panel 0BFB in the cavern for A.C. etc.

This comparison process shows that not only cost-wise but also from technical viewpoint, the outdoor switchgear should be adopted.

Tables

Table 1 (1/2) Comparison of SF6 Switchgear versus 132 kV Outdoor Switchyard

Possiblility	No. of Units		No. of TML		SF6		132kV	Cable			Costs*	Area	Cavr.	Service Bldg.		Gate
	2	3	1	2	Cavern	Outside	Switchy.	Interc.	Tunnel	Shaft	E-Eq	m 2	m 2	A	B	House
A.1	X		X		X			X	X		6.5	100	364			X
A.2	X			X	X			X	X		8.9	200	418			X
A.3		X		X	X			X	X		9.8	200	480			X
B.1	X		X				X			X	3.2	1500	-	X		
B.2	X			X			X			X	3.4	1760	-	X		
B.3		X		X			X			X	4.4	2000	-	X		
C.1	X		X			X				X	5.6	100	-		X	
C.2	X			X		X				X	6.6	200	-		X	
C.3		X		X		X				X	7.9	200	-		X	
D.1	X		X			X			X		6.7	100	-		X	
D.2	X			X		X			X		7.7	200	-		X	
D.3		X		X		X			X		9.6	200	-		X	
E.1	X		X				X		X		4.2	1500	-	X		
E.2	X			X			X		X		4.7	1760	-	X		
E.3		X		X			X		X		6.1	2000	-	X		

* DM.10^6 (Deutsch Mark x 6th power of the tenth) Inclusive of CIF + Erection

Table 1 (2/2) Comparision of SF6 Switchgear versus 132 kV Outdoor Switchyard

Possibility	No. of Units	No. of T.M.L.	DM 10^6 * 46 MVA	DM 10^6 * 66 MVA
A1	2	1	32.3	38.8
A2	2	2	34.7	41.2
A3	3	2	47.7	-
B1	2	1	28.6	35.1
B2	2	2	29.1	35.6
B3	3	2	41.8	-
C1	2	1	31.1	37.6
C2	2	2	32.7	38.6
C3	3	2	45.3	-
D1	2	1	32.5	38.9
D2	2	2	33.4	39.9
D3	3	2	47.2	-
E1	2	1	29.9	36.4
E2	2	2	30.5	36.9
E3	3	2	43.7	-

A = SF6 in powerhouse, cable in access tunnel

B= 132 kV outdoor, cable shaft + Service Building, Type A

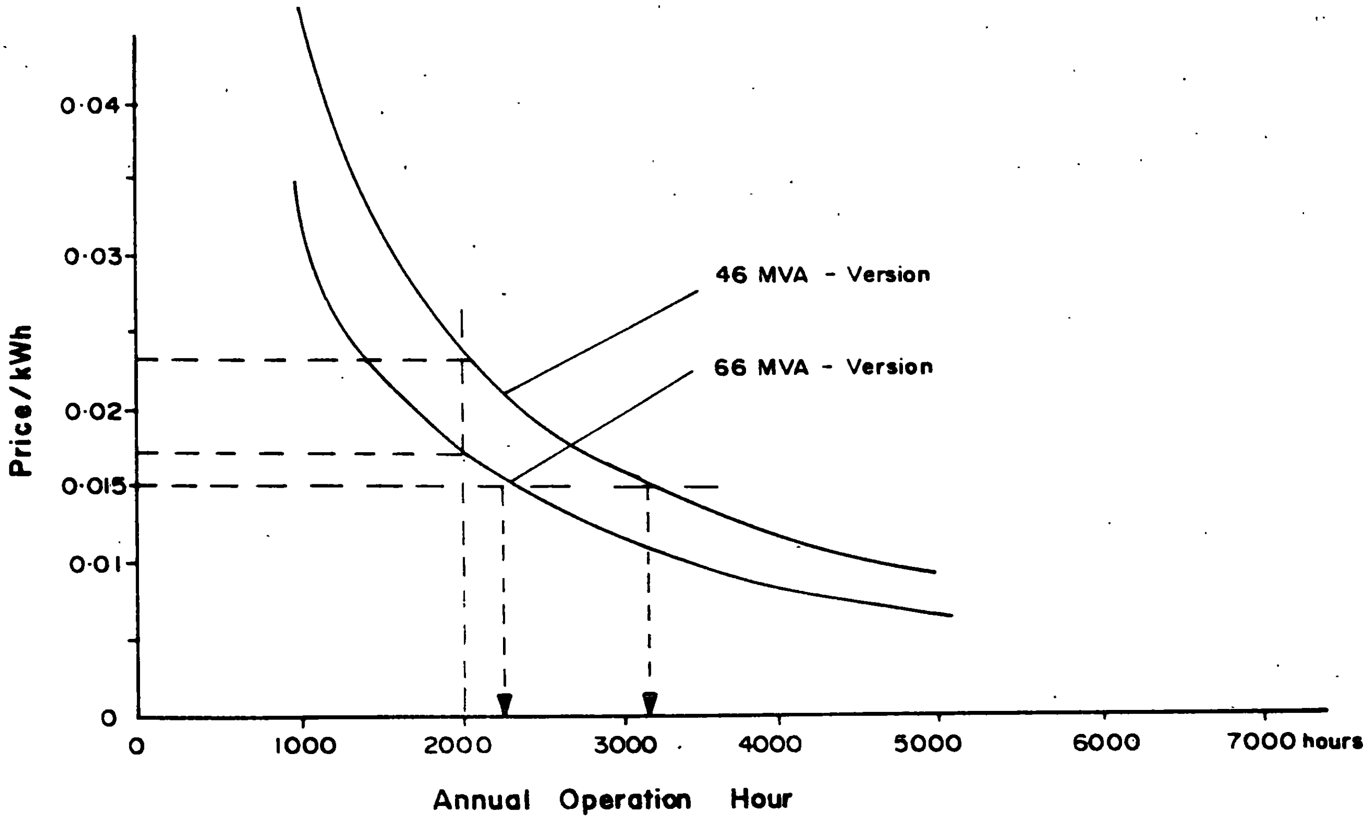
C= SF6 in Service Building, Type B, cable in shaft

D= SF6 in Service Building, Type B, cable - access - tunnel

E= 132 kV outdoor, cable in tunnel, Service Bldg., Type A

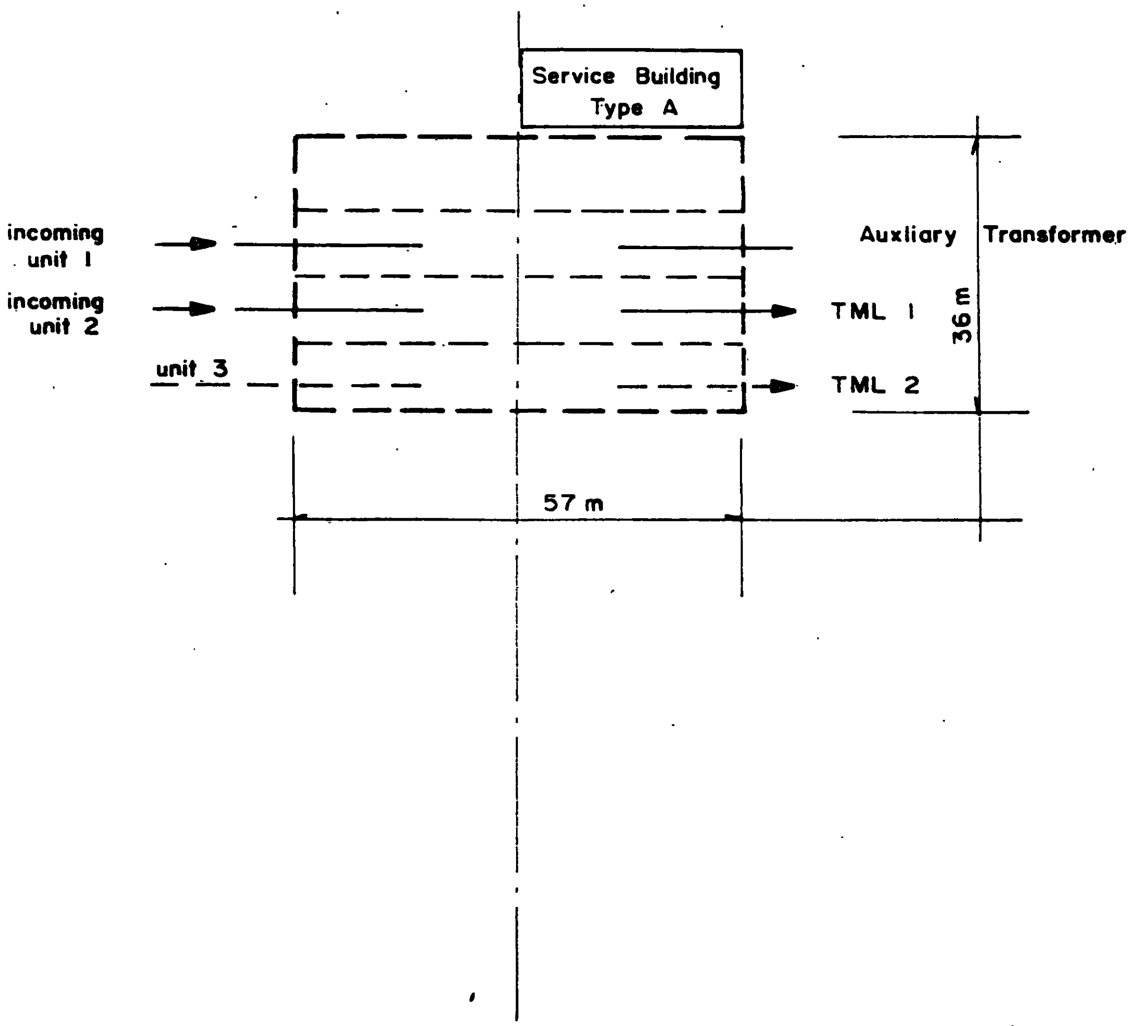
* Incl. CIF + erection

Figures



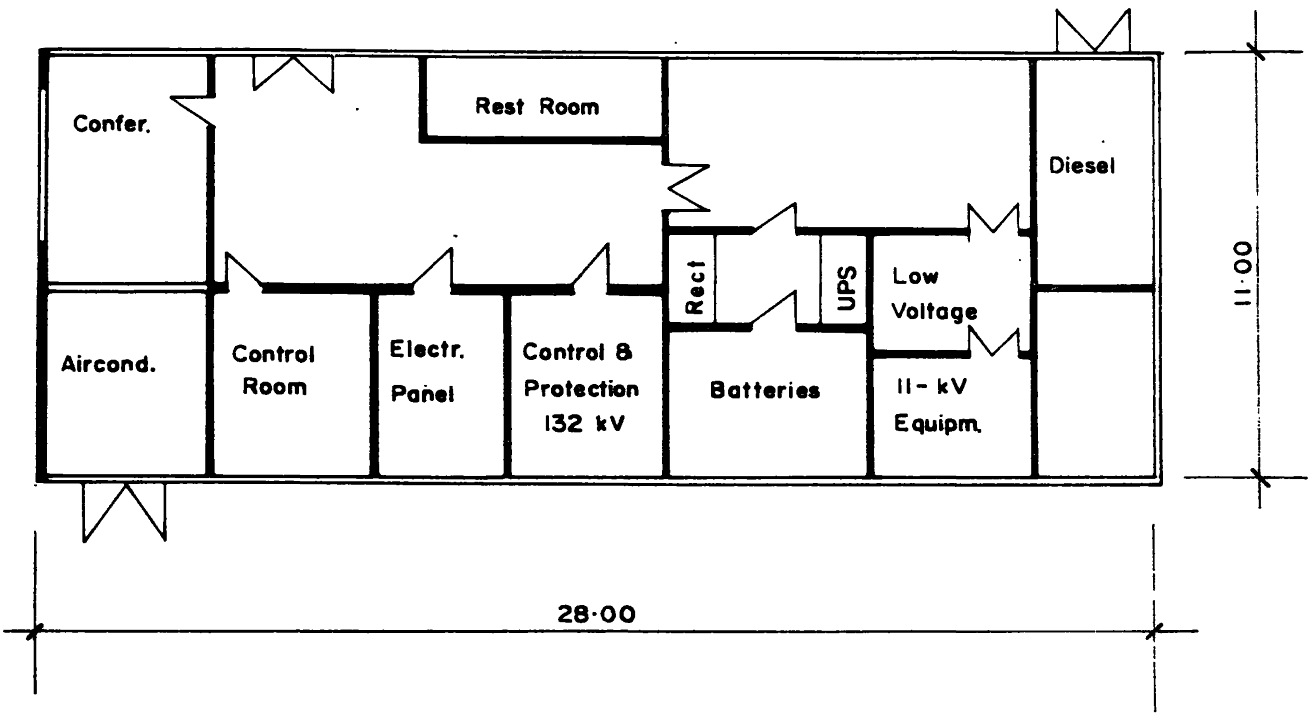
KUKULE GANGA HYDROPOWER PROJECT		**Figure 1.**
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	**Relationship of Generation Cost and Operation Hour**

LAYOUT 132 kV OUTDOOR SWITCHYARD WITH DOUBLE BUSBAR, TRANSVERSE LAYOUT

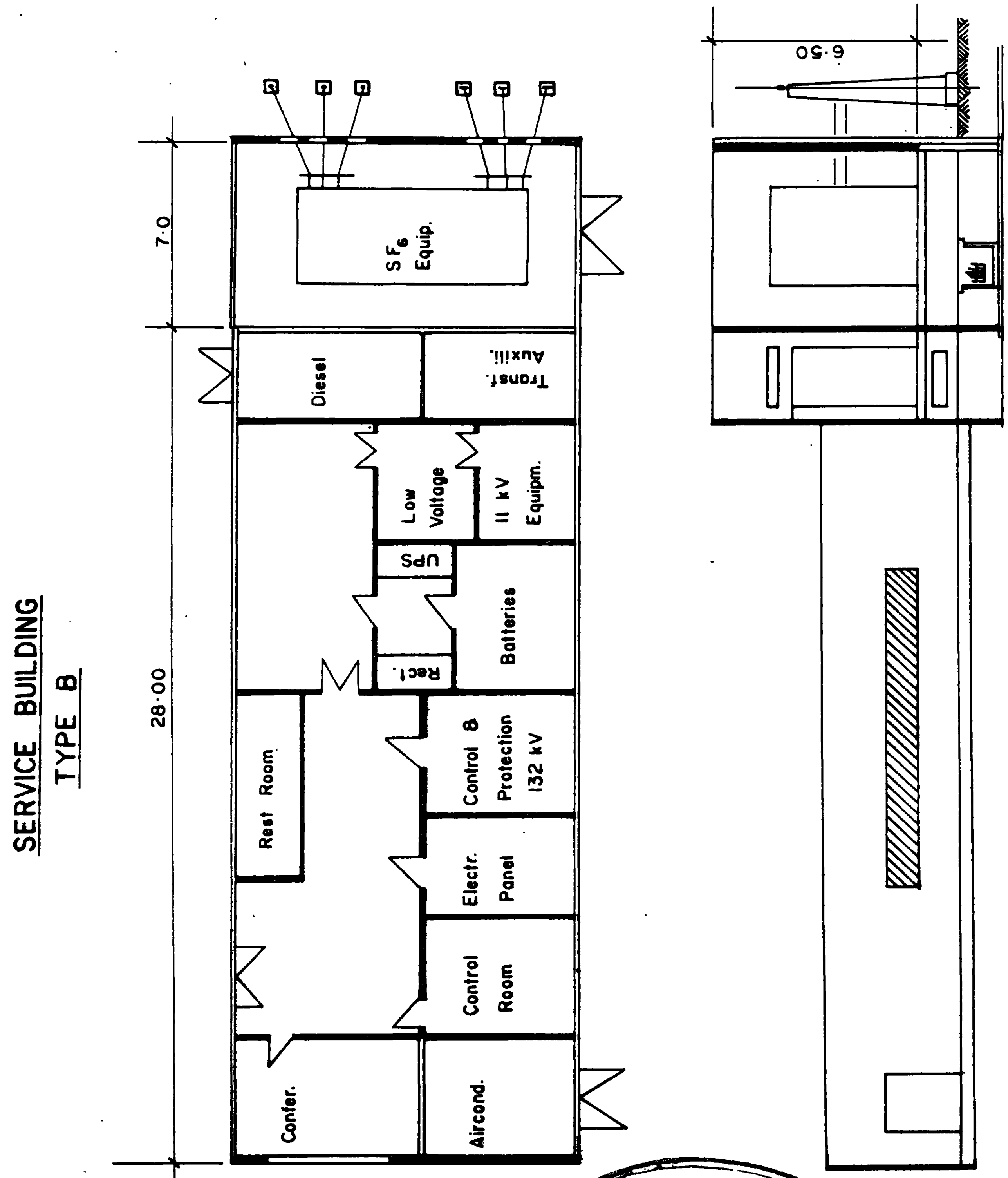


KUKULE GANGA HYDROPOWER PROJECT		Figure 2. Layout of 132 kV Outdoor Switchyard with Double Busbar
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	

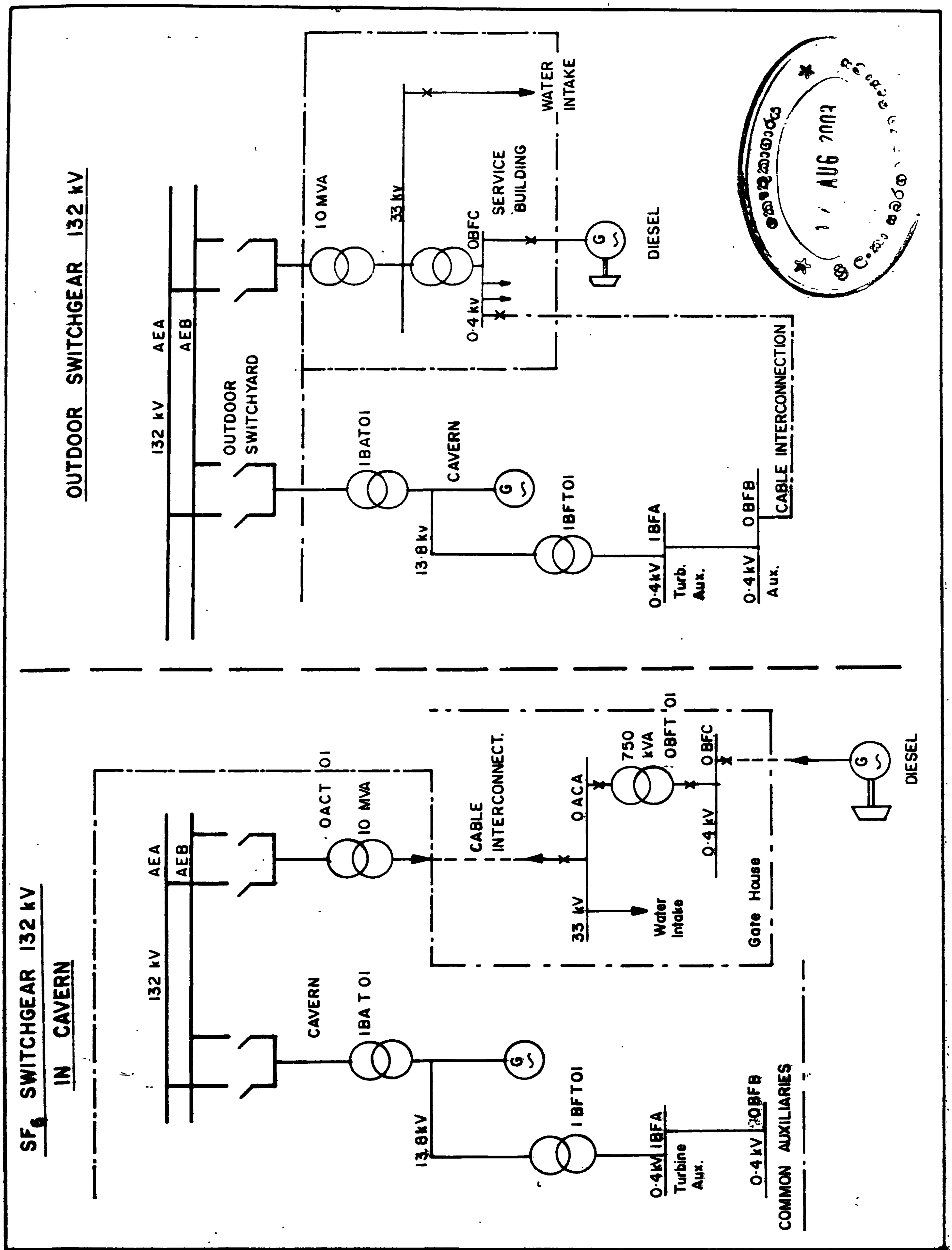
SERVICE BUILDING TYPE "A"



KUKULE GANGA HYDROPOWER PROJECT		Figure 3. Service Building, Type A
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	



KUKULE GANGA HYDROPOWER PROJECT		Figure 4. Service Building, Type B
Government of Sri Lanka Ministry of Power and Energy	Joint Venture Kukule Ganga NK, EWI & LI	
Ceylon Electricity Board	CECB, TEAMS, RDC	



KUKULE GANGA HYDROPOWER PROJECT		**Figure 5.** **Single Line Diagram of SF6 and Outdoor Switchgears**
Government of Sri Lanka **Ministry of Power and Energy** **Ceylon Electricity Board**	**Joint Venture Kukule Ganga** **NK, EWI & LI**	
	CECB, TEAMS, RDC	

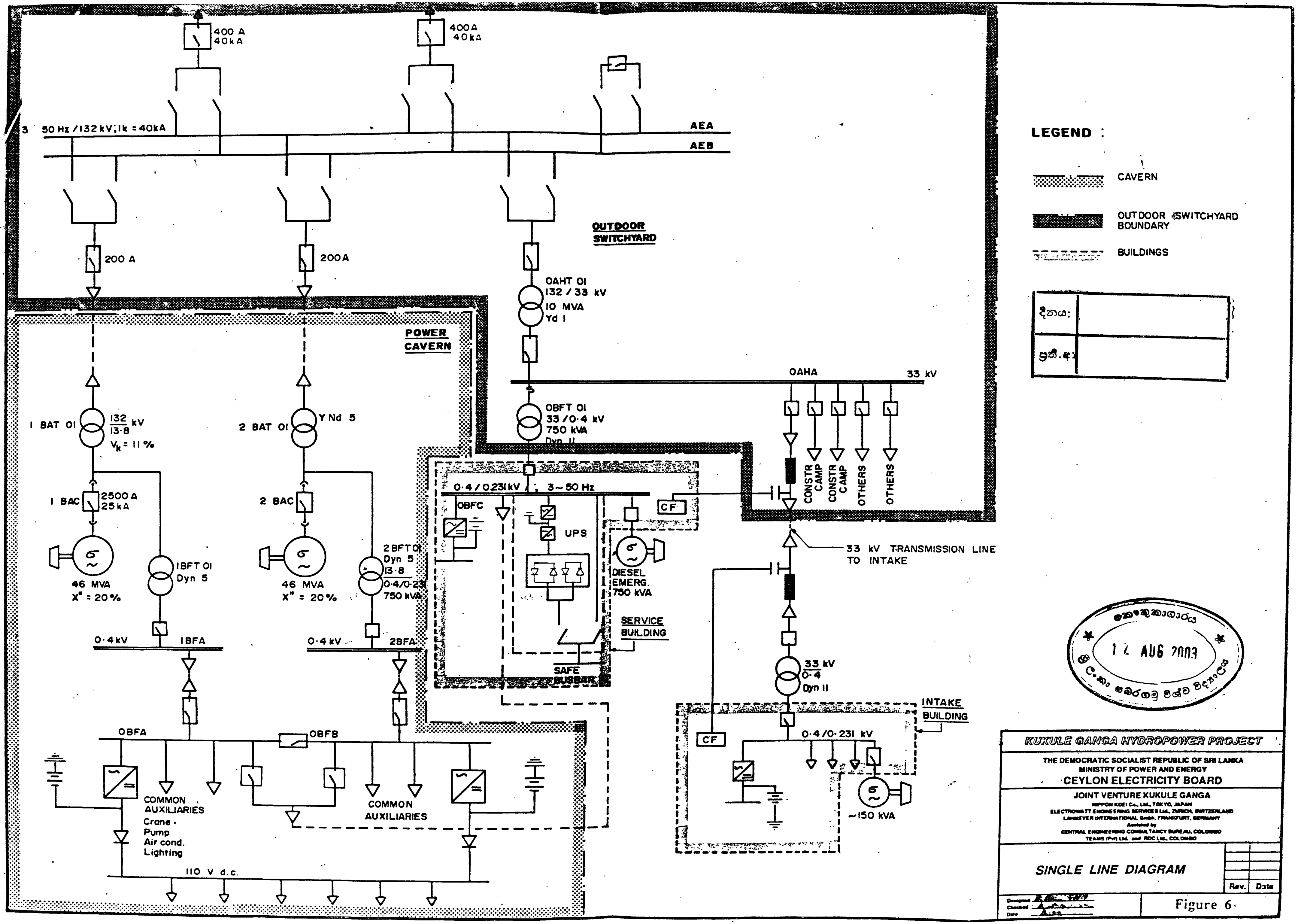

400 A 40 kA
400 A 40 kA
3 50 Hz / 132 kV; Ik = 40kA
AEA
AEB
200 A
200 A
OUTDOOR SWITCHYARD
OAHT 01 132 / 33 kV 10 MVA Yd 1
POWER CAVERN
OAHA
33 kV
OBFT 01 33 / 0·4 kV 750 kVA Dyn 11
1 BAT 01
132/13·8 kV
Vk = 11 %
2 BAT 01
YNd 5
1 BAC
2500 A 25 kA
2 BAC
46 MVA X" = 20%
46 MVA X" = 20%
1BFT 01 Dyn 5
2BFT 01 Dyn 5 13·8 0·4/0·231 750 kVA
0·4 / 0·231 kV
3 ~ 50 Hz
OBFC
UPS
CF
CONSTR CAMP
CONSTR CAMP
OTHERS
OTHERS
DIESEL EMERG. 750 kVA
33 kV TRANSMISSION LINE TO INTAKE
SERVICE BUILDING
SAFE BUSBAR
0·4 kV
1BFA
0·4 kV
2BFA
33 kV 0·4 Dyn 11
INTAKE BUILDING
CF
0·4/0·231 kV
~150 kVA
OBFA
OBFB
COMMON AUXILIARIES
Crane
Pump
Air cond.
Lighting
COMMON AUXILIARIES
110 V d.c.
LEGEND :
CAVERN
OUTDOOR SWITCHYARD BOUNDARY
BUILDINGS
දිනය:
ප්‍රති.අ:
14 AUG 2003
KUKULE GANGA HYDROPOWER PROJECT
THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA
MINISTRY OF POWER AND ENERGY
CEYLON ELECTRICITY BOARD
JOINT VENTURE KUKULE GANGA
NIPPON KOEI Co., Ltd., TOKYO, JAPAN
ELECTROWATT ENGINEERING SERVICES Ltd., ZURICH, SWITZERLAND
LAHMEYER INTERNATIONAL GmbH, FRANKFURT, GERMANY
Assisted by
CENTRAL ENGINEERING CONSULTANCY BUREAU, COLOMBO
TEAMS (Pvt) Ltd. and RDC Ltd., COLOMBO
SINGLE LINE DIAGRAM
Rev.
Date
Designed
Checked
Date

Figure 6

THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

MINISTRY OF POWER AND ENERGY

CEYLON ELECTRICITY BOARD

KUKULE GANGA HYDROPOWER PROJECT

FEASIBILITY STUDY

SR8C Transmission Line Works

August 1992

Joint Venture Kukule Ganga

Nippon Koei Co., Ltd.
Electrowatt Engineering Services Ltd.
Lahmeyer International Gmbh

Counterpart Engineers

Central Engineering Consultancy Bureau
TEAMS & RDC

FEASIBILITY STUDY
OF
KUKULE GANGA HYDROPOWER PROJECT

SR8C TRANSMISSION LINE WORKS

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CHAPTER I — OPTIMIZATION STUDY OF TRANSMISSION LINE SYSTEM

1.1 Introduction

To deliver the power out of the power plant and into the 132 kV CEB Grid System, as previous investigations already show, there are two nearest points of the 132 kV grid which have to be considered: Matugama S/S, about 27 km SWW from the future hydro plant Kukule Ganga and Pannipitiya S/S, about 52 km NNW from the plant. The existing 132 kV Matugama Substation is connected to the Grid System by a 132 kV double circuit line which begin at 132 kV busbars Colombo - Pannipitiya. This existing line is about 48 km length and is equipped with main conductor type "GOAT" (ACSR, 324/76 mm^2 per phase, acc. BS 215/70). According to the load forecasting worked out by CEB, the Matugama load centre will need in year 2001 (date in which the Kukule Ganga P.S. is provided to go in commercial operation) a total load of 37.4 MVA.

Taking into account on the apparent power (in MVA) which has to be transmitted from Kukule Ganga P.S. in the CEB Grid System in various options (see the enclosed Table 1.1.1) and under the assumption that this P.S. will be interconnected with the a.m. grid in Matugama S/S, the apparent power which can not be consumed in Matugama should be transmitted on the existing 132 kV double circuit line from Matugama S/S to Colombo (see these power values in the enclosed Table 1.1.2).

The site and design particulars for the electrical equipment and for the transmission line are given in the Table 1.1.3.

1.2 Interconnection of Kukule Ganga P/S to 132 kV CEB Grid System

Comparison of Various Variants

The apparent power which has to be delivered from the Power Station Kukule Ganga in the CEB Grid System in all three options of the P/S are indicated in Table 1.1.1, i.e. :

Option 1	91	MVA
Option 2	132	MVA
Option 3	131.8	MVA

The delivery of these power in the CEB 132 kV Grid can be made (in each one of the above mentioned options) in the following variants:

VARIANT "A": Delivery from Kukule Ganga P/S to existing Matugama S/S through:

- alternative A1, one O.H. transmission line, 132 kV, double circuit, about 27.2 km length or

- alternative A2, two separate O,H. transmission lines 132 kV, single circuit line, each of about 27.2 km length.

VARIANT "B": Delivery from Kukule Ganga P/S to existing Colombo-Pannipitiya S/S, through one O.H. transmission line, 132 kV, double circuit, about 47 km length (see also the enclosed figure No: 1.2.1).

The evaluation of the investment costs for all three interconnection variants of the Kukule Ganga P/S are given below (for each equipment option of the P/S) in the following tables:

- Table 1.2.1 Investment costs for the interconnection in Variant "A", alternative A1.

- Table 1.2.2 Ditto for Variant "A", alternative A2

- Table 1.2.3 Ditto for Variant "B"

The comparison of investment costs in the Table 1.2.4 shows that for all options to equip the Kukule Ganga P/S the most advantageous solution is the variant "A", alternative "A1".

As the operational costs (fixed and variables) are also minimum in all options for the Variant "A" alternative A1, we retain this solution for the interconnection of the power plant to the CEB Grid System.

1.3 Transmission Line Voltage and Number of Circuits

As rated voltage for the transmission line from Kukule Ganga P/S to the CEB Grid System the standard values of 132 kV (double circuit) or 220 kV (single circuit) can be considered.

The transmission load of the line should be per circuit in the vicinity of the surge impedance load. As known the design of the line for this value of the load per circuit assume the most economical conditions for the transmission.

In Table 1.3.1 the surge impedance load for different rated voltage of the transmission circuits are presented.

We note that the recommendable rated voltages for the transmission of the power given in Table 1.1.1 (from the power station to the CEB Grid) are related to the above considerations both voltages 132 kV (two circuits) and 220 kV (one circuit). Taking into consideration also that:

a) the most proximate connection point to the CEB present day Grid System is the 132 kV Matugama S/S

b) two circuits solution offer a bigger reliability and more elasticity in operation (By a failure in one circuit the second can transmit, under the thermal limit, the entire power of the power station)

c) two circuits solution improve the transient stability conditions of the CEB Grid System in comparison to the one circuit solution

d) the two circuits solution give better possibilities to repair or to execute the maintenance work on one of two circuits.

We propose the solution for Two circuits at rated voltage 132 kV to be retained for the transmission line from the Kukule Ganga P/S to the CEB Grid for all three equipment options of the power station.

1.4 Type of Tower

After the lay-down of the transmission line voltage and the number of circuits, a type for line tower has to be selected.

The comparison should be worked out between the following solutions for 132 kV transmission lines:

- Two separate single lines and
- One double circuit line

We propose to take the decision for a double circuit line for the following reasons:

- The investment costs are smaller with about 30% (reduced cost for supply, transport and.erection)
- Smaller maintenance cost
- Smaller right-of-way and tower estate area costs
- Reduced environmental (visual) impacts in the picturesque landscape of the region

With regard of the type of the tower for two circuits line, we propose the solution of tower provided with three cross-arms (for the main conductors) because:

- Necessitate smaller place
- Necessitate smaller width for the line route
- To conform with the CEB experience in the design and maintenance work of other double circuit lines in Sri Lanka.

Taking into account the relative high value for the isokerannic level in Sri Lanka and of CEB experience in this country we propose that the double circuit line shall be protected against atmospherical over-voltages accordingly by design of the line with two earth-wires.

1.5 Cross Section and Type of the Main Conductors

1.5.1 General

Selection of the main conductors should be made taking into account of the following:

- Apparent power which has to be transmitted on each circuit (continuous load in normal operation and exceptional load by failure of one circuit), as per Table 1.1.1
- Site conditions and design particulars
- Economical current carrying capacity
- Surface voltage gradient and corona losses
- Mechanical stresses in operation
- Conductor under thermal short circuit strength. To deliver the power out of the plant and into the CEB Grid System, as previous investigations already show, a double circuit line of 132 kV should be recommended. This line shall take off from 132 kV busbar of the Kukule Ganga switchyard and shall terminate at the existing 132/33 kV Matugama S/S. The length of this line will be about 23 km.

For this line which has to be erected in a relatively flat terrain we select ACSR conductor with steel/aluminium ratio of 1:6.

The double circuit line shall be sized in various options of the Kukule Ganga P/S as follows:

- Option 1: 2 x(3 x 240/40 mm^2) ACSR, (outer diameter of the conductor 21.8 mm) acc. to DIN 48204

- Option 2: 2 x(3 x 300/50 mm^2) ACSR (outer diameter 24.5 mm)

- Option 3: as per option 2

The checking of these chosen conductors has been made as follows:

1.5.2 Maximum Current-Carrying Capacity

The Maximum carrying capacity has been calculated for all options according to "'ALCOA' Conductor Engineering Hand-book", considering the site conditions and design particulars indicated in Table 1.5.1.

The chosen conductors can carry, under normal conditions, the apparent power per circuit indicated in Table 1.5.2 and in emergency case (one circuit from two disconnected), the total output of the power station mentioned in Table 1.5.1.

1.5.3 Economical Cross Section of the Main ACSR Conductors

The economical cross section of the main ACSR conductors has been calculated for all options according to the methodology presented in "SIEMENS" book "Starkstromtechnik II", considering the same site and design particulars as indicated above as well as:

- Interest of investment : 10% per year
- Depreciation of line : 3% per year
- Cost of maintenance works : 1% per year (from investment costs)
- Ratio between minimum and maximum load: 0.25, respectively 0.18 for the Options 2 and 3
- Operation time of the max. load: 4479/3500 h/year
- Cost of energy (in year 2001): about 12.5 Pf

As per Table 1.5.2 the results of calculations indicate the following economical cross section of the ACSR conductors:

Option 1 at maximum transmitting power of 91 MVA, the cross section of 203 mm^2 aluminium per phase.

Options 1 & 3	at maximum transmitting power of 132 MVA, the cross section of 260 mm^2 aluminium per phase
Conclusion	The cross sections of the selected conductors are in the vicinity of the calculated economical cross section.

1.5.4 Surface Voltage Gradient

The calculations of the surface voltage gradient for both chosen conductors (see Table 1.5.3) show that the values are far from the maximum voltage gradient (18 to 21 kV/cm) admitted for the line in normal operation conditions. The calculated values of the surface voltage gradient are:

- For 240/40 mm^2. ACSR : 11.9 kV/cm
- For 300/50 mm^2. ACSR : 10.8 kV/cm

1.5.5 Thermal Short-circuit Strength

The thermal short-circuit strength has been calculated according to Siemens book "Kabel und Leitungen Fur Starkstrom", para 30.2. The calculation of the minimal cross-section of aluminium which has to be thermal stable by short circuit strength has been worked out under the following conditions and data:

- Three phase short-circuit power : 2500 MVA
- Disconnecting time of the failure : 0.5 s
- Initial temperature of the conductor before short-circuit : 80 ^oC
- Maximum temperature under short-circuit conditions : 160 ^oC
- Initial symmetrical short-circuit current : I''_k=10.94 kA. r.m.s.
- Peak short-circuit current : I_s =27.9 kA peak

The calculation under the above mentioned conditions give a value for the minimum cross-section aluminium of S_{min}=46.5 mm^2

Conclusion: The cross-section of the chosen conductors are substantially bigger as the calculated minimum of aluminium cross-section.

1.6 Transmission Line Route

1.6.1 Soil Conditions

The geological conditions along the envisaged alignment alternatives are characterised by the presence of gneissic rock types including biotite gneiss, garnetiferous, quartz-feldspar gneiss and charnockite. The rock mass is generally covered by weathering products of the parent rock. In low lying areas alluvial deposits are accumulated. Therefore, foundation conditions that will be encountered along the transmission line can be broadly divided into 3 groups:

- foundations on fresh and slightly weathered rock
- foundations on overburden (residual soil, highly weathered rock)
- foundations on alluvial deposit (sandy, silty, clayey soils of up to 5 m thickness).

Currently, no landslides or general foundation instability conditions have been identified.

1.6.2 Selection of the Line Route

The proposed transmission line routing has been selected from the studies of a series of 1:63,600 and 1:10,000 topographic maps. The terrain between Kukule Ganga P/S and Matugama S/S is situated in a hilly region with a lot of paddy field cultures in the valleys. The altitude over sea level vary from 320 m to 170 m in the vicinity of the service buildings of the power station and at about 100 m o.s.l. in the vicinity of the Matugama S/S.

The line route should be as close as possible to the access roads and basically follow the crests of the hills for better foundation conditions.

1.6.3 Description of the Line Routes

The chosen route No. 1 begins at the 132 kV switch-yard of the power station Kukule Ganga. After it traverse the Peleng River it continues in the region of Maha Pattu North passing near the village Omatta. Beyond a paddy field area beside the village from Yatiyana it continues north of the village of Matugama and comes to the switch-yard 132/33 kV Matugama (see drawing No. 21). The total length of this route is 27.2 km.

The chosen route No. 2 (see also the same a.m. drawing) run after the outgoing from the Kukule P/S about 11 km parallel to the route No. 1 but 2-3 km to the north of this route. The route No. 2 deviate to the north of the village Pantiya down to the switch-yard and Matugama. The length of this route is 28.1 km.

By comparison of the two line routes No.1 is chosen as the line route for the transmission line 132 kV Kukule Ganga P/S - Matugama S/S which is shorter by about 1 km compared with the line route No. 2.

CHAPTER II PROPOSED TRANSMISSION LINE & SUBSTATION

2.1 Introduction

The power station Kukule Ganga shall be connected to the CEB Grid System by an 132 kV, O.H. double circuit transmission line.

This line shall take off from 132 kV busbar system of the P/S Kukule and shall terminate at the existing 132/33 kV S/S in Matugama. The length of this double circuit line will be about 27 km and the conductors shall be sized various options of the power station Kukule Ganga (see Table 1.1.1) as follows:

Option 1 : 2 x(3 x 240/40 mm^2 ACSR), for the power of 45.5 MVA/ circuit

Option 2 : 2 x(3 x 300/50 mm^2 ACSR), for 66.0 MVA/circuit

Option 3 : 2 x(3 x 300/50 mm^2 ACSR), for 65.9 MVA/circuit

The design construction and protection criteria given in the following paragraphs 2.2.1 to 2.2.6 shall be applied for the different components of this transmission line.

2.2 Transmission Line 132 kV to Matugama S/S

In the following will be presented the most important components of this double circuit line.

2.2.1 Towers

The towers for the transmission line shall be of the self-supporting, galvanized, lattice steel frame type with square base.

All structural steel including grillage footings shall be galvanized after manufacturing galvanized by the hot-dip process (with 600 g/m^2 coating of zinc, at minimum, according to relevant D/N or ASTM standards).

The double circuit towers will be designed with three cross-arms for the main conductors. Two earth-wires of ACSR conductor, each of cross section 95/15 mm^2 has to be also provided in the top of the tower.

The conductors of each three phase circuit shall be in vertical position of the left or on the right of the centre line of the tower.

A diagram of a similar suspension tower for a double circuit line 132 kV is indicated in the Fig. 2.2.1.

2.2.2 Foundations

The tower foundations should be normally of mass concrete or reinforced concrete. The foundation of each tower shall consist of four footings. In good soil conditions for suspension tower, the grillage footings can be used. Where the foundation type are not applicable other forms of foundations such as raft or pile foundations should be used.

Rock anchor foundations can be used for areas where footings may be secured to solid bedrock by means of tension members grouted into rock. The foundations will have a factor of safety against uplift greater than 2.0 in the case of normal loading conditions.

2.2.3 Grounding of Tower Structures

The grounding of tower structures shall be made as required by soil conditions and according to earth resistance at each of the tower location. Two (or more) ground rods per tower should be installed according to the requirements of the measured earth resistance.

For tower locations where rods can not be used due to soil conditions, ground strips should be installed.

The ground ohmic resistance of each tower structure, measured prior to the installation of the overhead earthwires, shall not be greater than 15 ohm.

2.2.4 Conductors

As per above item 2.2.3 the conductors for the 132 kV double circuit line to Matugama have been proposed, in the different options for the construction of the Kukule P/S as given in the table 2.2.1.

The cross section of the main conductors have been determined (see above para 1.3) taking into consideration:

- the maximum current-carrying capacity (thermal current rating)
- economical cross-section (at economical current-carrying capacity)
- the outer diameter to avoid corona effect (at minimum 18 mm)

2.2.5 Insulator Strings

Insulator strings should be composed of individual insulator units type 255 x 146 mm, according to IEC 383/1983 (or 10 x 5 3/4 inches, according to ANSI, C.29.1), consisting of glazed porcelain (or toughened glass) shell and metallic caps and pins with ball and socket fittings.

The number of units per string shall be as follows:

- for suspension strings (vertical position) : 10 units
- for tension strings (horizontal position) : 11 units

According to IEC publication 383/1983 the insulator string should be tested by following voltages:

		Suspension String	Tension String
Power Frequency Withstand Voltage (kV r.m.s.)	Dry	510	550
	Wet	375	410
Lightning Impulse Withstand Voltage (kV peak)		800	880

All insulator strings should be equipped with arcing rings or horns. The design of the arcing rings shall be such as to reduce as far as possible damage to the conductor, clamps, insulator strings and arcing horns themselves under all flashover conditions.

2.2.6 Calculations of the O.H. Transmission Lines

The complete calculations of the proposed transmission lines are enclosed in the annexes 8C.1 to 8C.4.

2.3 Supply of the Auxiliary Services in Intake Area

In normal operation all electrical consumers in the INTAKE area should be supplied from the power station through:

- a 11 kV O.H. single circuit line, equipped with conductor 3 x 50 Alu and of about 7.5 km total length, on galvanized lattice steel frame towers and over.
- a pole mounted substation 11/0.4 kV (beside the INTAKE) equipped with one three-phase transformer of 160 kVA rated power.

The route of this O.H. line shall begin at the Service Building of the P/S, go along the construction road to Tunnel Adit No. 2 (about 4.5 km) and shall finish over a tract of land (from about 3 km) to the INTAKE place where the above mentioned pole mounted substation 11/0.4 kV shall be erected.

2.4 Extension of Matugama S/S

For the connection of the two circuits 132 kV, coming from Kukule Ganga P/S, the extension of Matugama S/S with two incoming bays as well as the erection of a 132 kV busbar system are necessary. The extension of this S/S with the above mentioned components require the enlargement of the existing 132 kV switchyard area in width of about 2 x 9 = 18 m (i.e. the width of two new incoming bays).

The related values for the new electrical equipment (with which the S/S has to be extended) should be:

- Rated voltage	132 kV
- Highest system voltage	145 kV
- Rated current for the circuit breaks & disconnectors	800 A
- Short circuit capacity, at minimum	2500 MVA
- System fault level (initial a.c. component)	I''_k=11 kA r.m.s.
- Short-circuit peak value	I_S =28 kA peak

2.5 Power Line Carrier System

The communications from Kukule Ganga P/S to Matugama S/S and further to Colombo - Pannipitiya S/S shall be realized by means of a multipurpose power line carrier (PLC) in interphase system on the 132 kV transmission line.

The transmitted signals from Kukule Ganga P/S to Matugama S/S shall be carried further from Matugama S/S to Colombo - Pannipitiya S/S through the existing multipurpose PLC link.

The proposed PLC equipment covers speech, data and protection signalling for both lines. The line traps and coupling capacitors are separate. The PLC link is based on a double channel speech transmission, one 600 baud data channel and protection signalling equipment for each 132 kV transmission circuit (see enclosed sketch in Fig. 2.5.1).

The PLC system has to be very reliable in operation. The transmitting band of PLC channels should be coordinated (put-in of the transmitting frequencies in the national frequency plan) with SRI LANKA TELECOM.

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Tables

Table 1.1.1 Apparent Power (MVA) Which Has to be Transmitted (output from Power Station Kukule)

Option		Per Unit					Total Output (from P.S.)		
No.	Installed Power (MW)	Turbine Output (at shaft) (MW)	Generator Efficiency (%)	Main Transformer Efficiency (%)	Power Factor	Transformer Output (at H.V. terminals) (MVA)	No. of Units	Apparent Power Which Has to Be Transmitted	
								Per Double Circuit Line (MVA)	Per Circuit (MVA)
1	2 x 39.90	39.90	0.98	0.99	0.85	45.5	2	91.0	45.5
2	3 x 38.55	38.55	0.98	0.99	0.85	44.0	3	132.0	66.0
3	2 x 57.72	57.72	0.98	0.99	0.85	65.9	2	131.8	65.9

Table 1.1.2 132kV Existing Line (Matugama - Colombo)

(Double circuit equipped with 324/76mm2 ACSR per phase*)

Transmitted Power from Matugama S/S to Pannipitiya S/S

Option		Power from P.S. Kukule Ganga to Matugama S/S MVA	Total load centre (Year 2001) Matugama MVA	Power from Matugama to Colombo - Pannipitiya MVA
No.	Installed power of P.S. Kukule (MW)			
1	2 x 39.90	91	37	54
2	2 x 38.55	132	37	95
3	2 x 57.72	132	37	94

* Conductor "GOAT", acc. to BS 215/70, Part 2

Table 1.1.3 Site and Design Particulars

A. SITE CONDITIONS

The site conditions are assumed to be as following:

Conditions

- Altitude of Site (above Sea Level)	:	160 masl
- Ambient Temperatures		
Maximum	:	40° C
Minimum	:	15.5 ° C
Average	:	32° C
- Seismic Acceleration	:	0.1 g (horizontal); see RANDENIGALA H.P. Project
- Isokeraunic Level	:	70
- Relative Humidity		
Maximum	:	91 %
Minimum	:	67 %
- Rainfall		
Average Annual	:	4500 mm/year, in Kukule Ganga P/S area
	:	3800 mm/year, in Matugama S/S area

B. ELECTRICAL PLANT DESIGN CRITERIA - (132 kV PART OF S/S)

General

- Nominal system voltage between phases	kV r.m.s.:	132
- Highest system voltage between phases	kV r.m.s.:	145
- Lightning impulse withstand voltage (1.2/50.µs)	kV peak :	650
- Power frequency (1 minute) withstand voltage	kV r.m.s.:	275
- System frequency	Hz :	50
- System earthing	:	Solidly grounded
- System fault level (I''_k)	kA r.m.s.:	11.0
- Peak short circuit value	kA peak :	28.0

Table 1.2.1 Interconnection of Kukule Ganga P/S to 132 kV Grid

VARIANT "A", ALTERNATIVE "A1"

Item	Description	Unit Price		OPTION						Remarks
				1		2		3		
		Unit	Price DM	Number/ Length	Total (DM)	Number/ Length	Total (DM)	Number/ Length	Total (DM)	
1	Transmission O.H. line, 132kV, double circuit, equipped with conductor 3 x 240/40 ACSR	km	226,000	27.20	6,147,000					
2	Ditto, with conductors 3 x 300/50 ACSR per circuit	km	243,000			27.20	6,610,000	27.20	6,610,000	
3	132kV incoming bay in Matugama S/S, 2500 MVA, 800A, complete	Bays	700,000	2.00	1,400,000	2.00	1,400,000	2.00	1,400,000	
4	Total				7,547,000		8,010,000		8,010,000	

Table 1.2.2 Interconnection of Kukule Ganga P/S to 132 kV Grid

VARIANT "A", ALTERNATIVE "A2"

Item	Description	Unit Price		OPTION 1		OPTION 2		OPTION 3		Remarks
		Unit	Price DM	Number/ Length	Total (DM)	Number/ Length	Total (DM)	Number/ Length	Total (DM)	
1	Transmission O.H. line, 132kV, single circuit, equipped with conductor 3 x 240/40 ACSR	km	137,000	54.40	7,453,000					
2	Ditto, with conductors 3 x 300/50 ACSR per circuit	km	148,000			54.40	8,051,000	54.40	8,051,000	
3	132kV incoming bay in Matugama S/S, 2500 MVA, 800A, complete	Bays	700,000	2.00	1,400,000	2.00	1,400,000	2.00	1,400,000	
4	Total				8,853,000		9,451,000		9,451,000	

Table 1.2.3 Interconnection of Kukule Ganga P/S to 132 kV Grid

VARIANT "B"

Item	Description	Unit Price		OPTION						Remarks
				1		2		3		
		Unit	Price DM	Number/ Length	Total (DM)	Number/ Length	Total (DM)	Number/ Length	Total (DM)	
1	Transmission O.H. line, 132kV, double circuit, equipped with conductor 3 x 240/40 ACSR	km	226,000	47	10,622,000					
2	Ditto, with conductors 3 x 300/50 ACSR per circuit	km	243,000			47	11,421,000	47	11,421,000	
3	132kV incoming bay in Pannipitiya S/S, 2500 MVA, 800A, complete	Bays	700,000	2	1,400,000	2	1,400,000	2	1,400,000	
4	Partial rehabilitation of S/S Pannipitiya to permit extension	Sum	300,000	1	300,000	1	300,000	1	300,000	
5	Total				12,322,000		13,121,000		13,121,000	

Table 1.2.4 Interconnection of Kukule Ganga P/S to 132 kV Grid

COMPARISON OF INVESTMENT COSTS IN DIFFERENT VARIANTS

Item	Description	Unit Price		OPTION						Remarks
				1		2		3		
		Unit	Price DM	Number/ Length	Total (DM)	Number/ Length	Total (DM)	Number/ Length	Total (DM)	
1	VARIANT A, Altern. A1 Investment costs				7,547,000		8,010,000		8,010,000	
2	VARIANT A, Altern. A2 Investment costs				8,853,000		9,451,000		9,451,000	
3	VARIANT B Investment costs				12,322,000		13,121,000		13,121,000	
4	The most advantageous variant (in each option)				Variant A Alt. A1		Variant A Alt. A1		Variant A Alt. A1	

Table 1.3.1 Surge Impedance Load For Different O.H. Lines

Rated Voltage(kV)	Number of Circuits	Surge Impedance (ohm)	Surge Impedance Load (MW/circuit)
132	Single circuit	380	46
	Double circuit	340	51
220	Single circuit	370	131

Table 1.5.1 Thermal Current Rating of the ACSR Conductors Maximum Current-Carrying Capacity

(acc. to ALCOA Current-Temperature Rise Graph from ALCOA Conductor Engineering Handbook - Section 6)

Conductor size (mm2)	Thermal conditions for the conductors			Emissivity effect with sun	Altitude o.s.l. (m)	Max. Current carrying capacity (A)	Max.Transmitting power (per 132kV circuit), (MVA)
	Temperatures (in C)	Temp. rise dt (in C)	Wind m/s				
240/40	40/75	35	Still air	0.5	160	450	103
300/50	40/80	40	Still air	0.5	160	590	135

Table 1.5.2 Economical Cross-Section of the ACSR Conductors at Economic Current-Carrying Capacity

(acc. to the methodology from SIEMENS book "Starkstromtechnik II")

Option	Max. transmitting power (per two 132 kV circuits) (MVA)	Current per phase (per circuit) (A)	Economical current density (calculated) (A/mm2)	Economical cross section (Alu) of ACSR conductor (mm2 Alu/per phase)
1	91	199	0.98	203
2 & 3	132	289	1.11	260

Table 1.5.3 Surface Voltage Gradient of the Main Conductors

Option		Outer diameter of the conductor mm	Capacitive reactance of the circuit 10^5 ohmxkm/phase	Surface voltage gradiant	
No.	Conductor size mm2 ACSR			Maximum kV/cm	Calculated kV/cm
1	3x240/40	21.8	3.34	18	11.9
2	3x300/50	24.5	3.28	18	10.8
3	3x300/50	24.5	3.28	18	10.8

Table 2.2.1 132 kV Double Circuit Line To Matugama

Cross section of ACSR conductor (per phase)

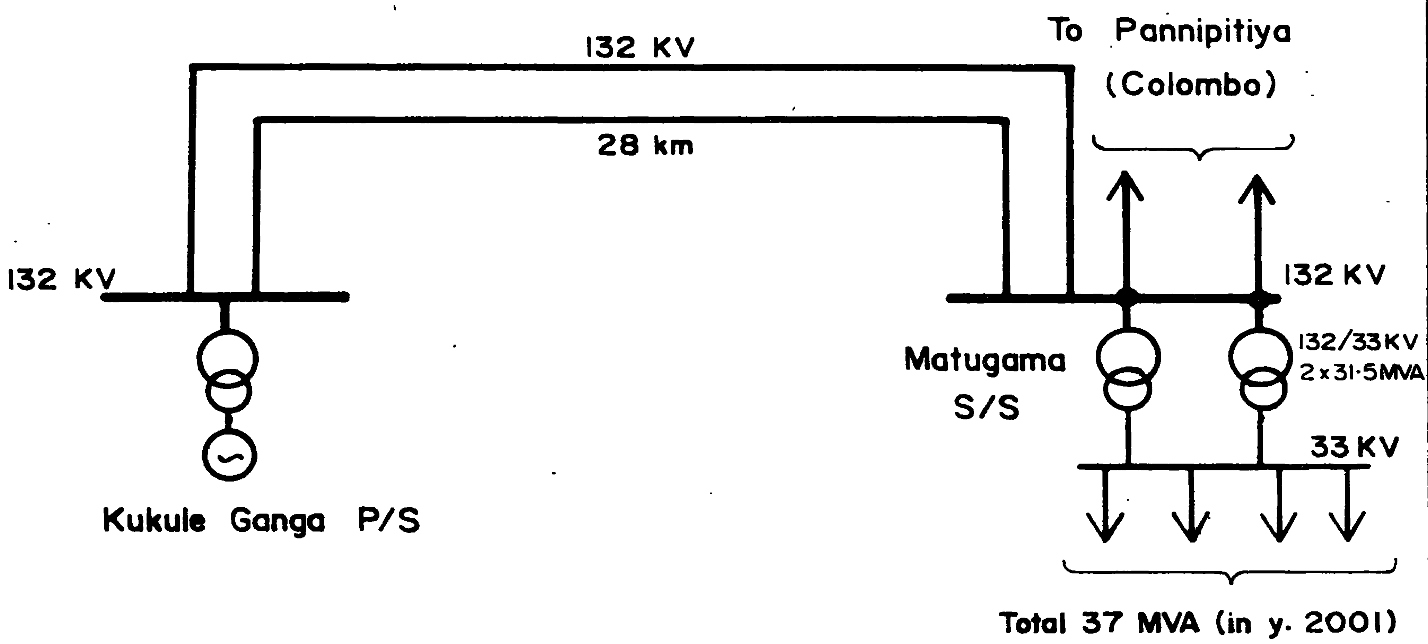
Option		Apparent power per circuit (MVA)	Proposed cross-section of the main conductor (per phase) (mm2)	Outer diameter of the conductor (mm)
No.	Installed power (MW)			
1	2 x 35 MW	45.5	240 ACSR	21.8
2	3 x 35 MW	66	300 ACSR	24.5
3	2 x 50 MW	65.9	300 ACSR	24.5

Figures

VARIANT "A"

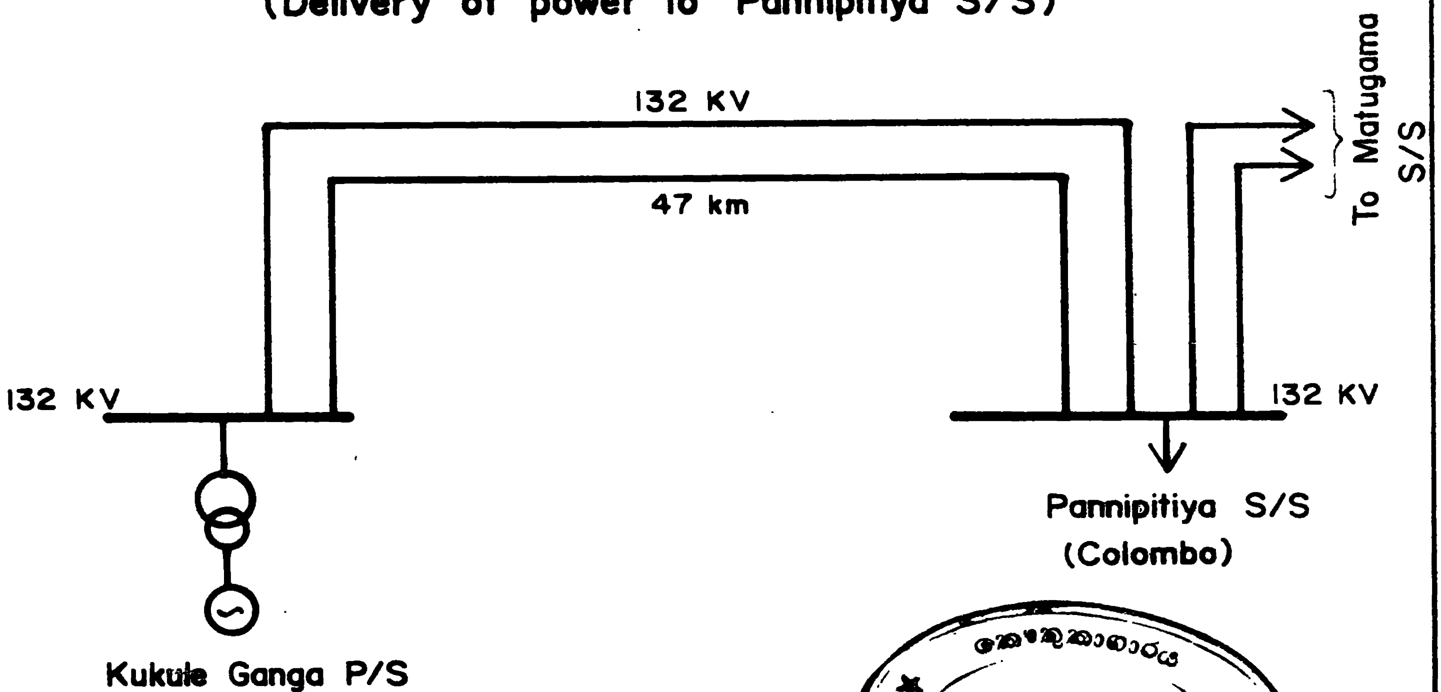
Alternatives A_1 and A_2

(Delivery of power to Matugama S/S)

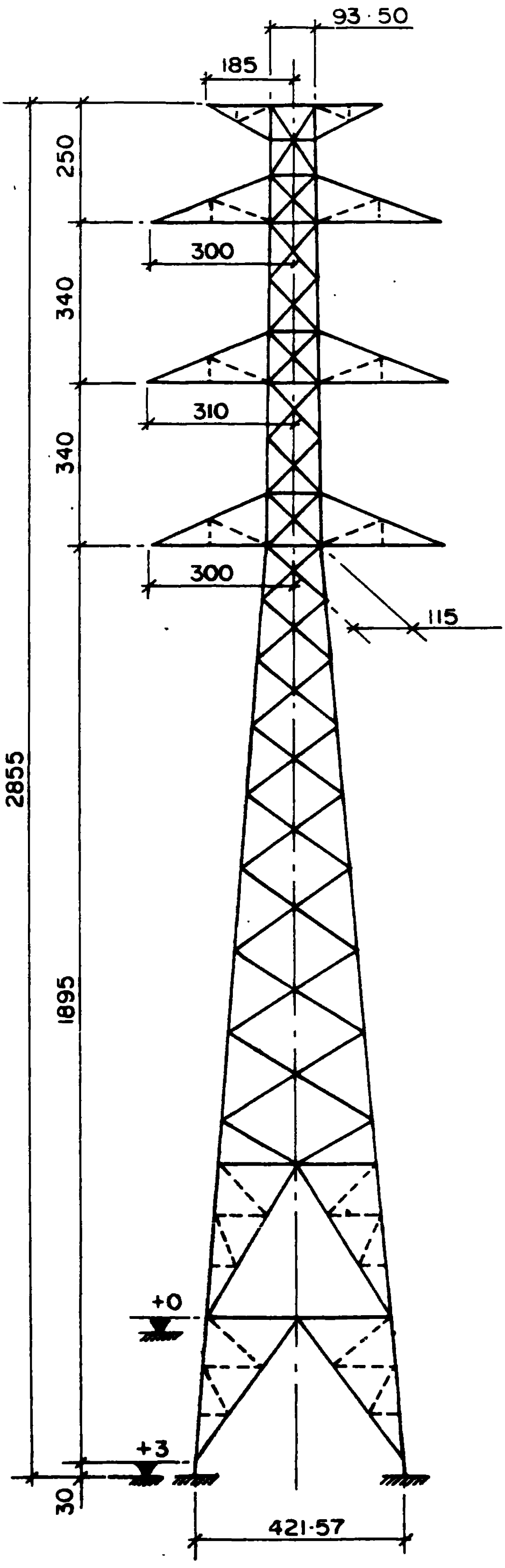


VARIANT "B"

(Delivery of power to Pannipitiya S/S)



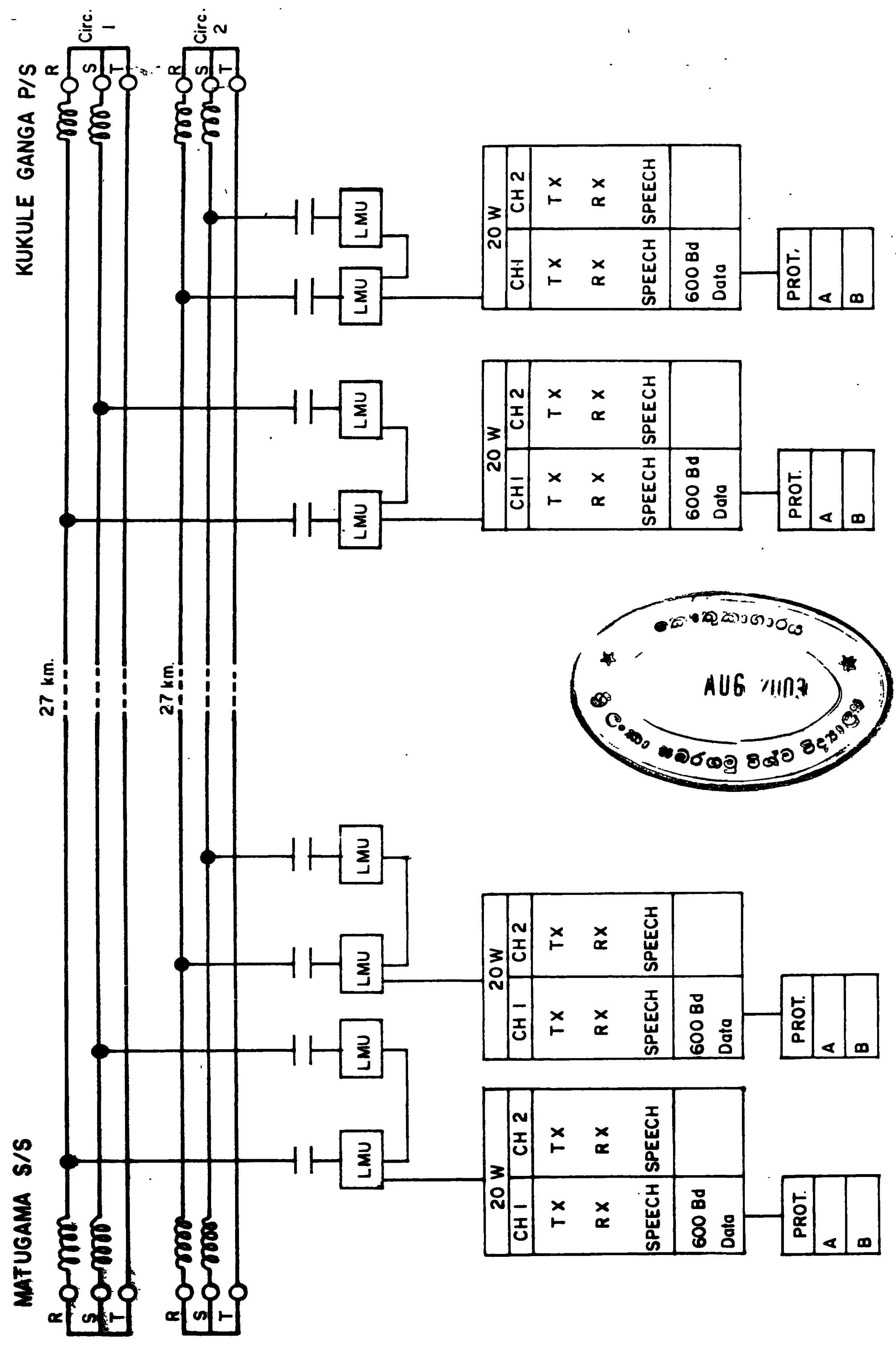
KUKULE GANGA HYDROPOWER PROJECT		Figure No. 1.2.1
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	Delivery of Power Variants "A" & "B"



TRANSVERSAL FACE

ALL DIMENSIONS ARE IN CM.

KUKULE GANGA HYDROPOWER PROJECT		Figure No. : 2 . 2. 1
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	Double circuit line 132 kV Suspension Tower



KUKULE GANGA HYDROPOWER PROJECT		FIGURE No. 2.5.1
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	**Power Line Carrier Link**

Annex-8C.1

T.L. Calculation Sheet for Option 1 (double cct.)

	132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Tonne/ 1

O V E R H E A D   P O W E R   L I N E

According to DIN VDE 0210 or equivalent standards
- Calculation of its characteristics -

Basic data

Name of the line : 132 KV - Db.circt line SRI LA3 Opt 1

Highest voltage of line	:	145 KV
Normal span length	:	320 m
Number of subconductors	:	1
Distance of subconductors	:	0 mm
Number of earth wires	:	2
Name of conductor	:	240/40 - Al/St
Name of earthwire	:	95/15 - Al/St
Tower shape	:	Tonne
Tower type	:	S
Foundation type	:	A
Insulator type	:	L
Climatic zone	:	T

Index explanations :

Tower type	S	:	Lattice steel towers
Foundation type	A	:	Pad & chimney foundation, concreted to undisturbed soil
	S	:	Pad & chimney foundation, concreted to shuttering
Insulator type	L	:	Longrod insulators
	K	:	Cap and pin type insulators
Climatic zone	E	:	Ice loading area
	T	:	Tropical area

Calculated by: LAHMEYER INTERNATIONAL
Consulting Engineers
Head Office
D-6000 Frankfurt(Main)71

Programm Nr.: 0105010E

132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.199 Annex: Tonne/

Technical data conductors - input

Name of conductor	:	240/40 - Al/St	
Relation of cross section	:	6	
Standart	:	DIN48204	
Total cross section	:	282.50	mm^2
Conductive cross section	:	243.05	mm^2
Conductor diameter	:	21.80	mm
Wire dia. outer layer	:	3.45	mm
Total weight	:	0.9850	kg/m
Nominal breaking load	:	86460.00	N
Ohmic resistance	:	0.119	Ohm/km
Resistivity	:	0.029	Ohm*mm^2/m
Cont.current carrying cap. at 35/80°C u. 0.6 m/s Wind velocity	:	645.00	A
Permissbl.max.work.stress	:	120.00	N/mm^2
Average tensile stress	:	56.00	N/mm^2
Ult.long term tens.stress	:	208.00	N/mm^2
Effect. mod.of elasticity	:	7.700E+04	N/mm^2
Coeff.of thermal expansion	:	1.890E-05	1/K
Round conductor			

Techn.data for calcul.of conduct.tensile stresses and sags-input

Every day stress : 18.00 % of nominal breaking load
15% - 18% without antivibration device
>18% - 21.5% with antivibration device

Conductor temperatures oC

T1 (EDS):	20.00	T2(high) :	75.00	T3 :	0.01
T4(Ice) :	-5.00	T5(low) :	5.00		

Factor of vertical additional load :	1.00
Factor of horizontal additional load:	1.00
Wind load fact.long term tens.load :	2.00

Dynamic wind pressure and aerodynamical drag coeff.acc.VDE 0210

Hight of the power line above ground m	Height of the suspens.point above ground m	Dynamic wind pressure q N/m²	Conductor diamet.d mm	Drag coeff. cf
0 bis 20	<= 15	440	<= 12.50	1.20
0 bis 200	<= 20	530	<= 15.80	1.10
	<= 40	530	> 15.80	1.00
	<= 100	680		
	<= 150	860	no round conduct.	1.30
	<= 200	950		
	> 200	950		

Basic data for tower shape construction - input

Name of tower shape	:	Tonne	
Tower shape index	:	A	
Width increasing index 1)	:	G	
Upper part tower body	:	5.00	
Lower part tower body	:	7.00	
Crossarm tie incline	:	15.00	Degree
Length difference of crossarm,	:	0.10	m
Length of step bolts	:	0.20	m
String length;	:	2.04	m
Heigth of metalparts string	:	0.40	m
VDE-clearance conduct.-ground,	:	6.23	m
Additional ground clearance	:	0.10	m
Projection protect.fittings	:	0.00	m
Projection accessories;	:	0.05	m
Lightning protection angle of earth wire	:	30.00	Degree
Additional cross arm length	:	0.20	m
Heigth of susp.swivel clevis or V-links	:	0.30	m
Additional tower height	:	0.10	m
Width of towerbody at top	:	1.31	m
VDE-Minimum clearance	:	0.93	m

Footnote:
1) Width increasing indices
G in Degree (Inclining of one leg member)
M in mm/m (in relation to half width of tower body)

	132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Tonne/ 5

Basic data for estimation towers a.foundation - input

Dynamic wind pressure and aerodynamical drag coefficient acc. VDE 0210 for towers, crossarms and insulators

Hight of the power line above ground m	Hight of the components above ground m	Dynamic wind pressure q KN/m²	Towertype	Drag coeff. cf
0 upto 20	<= 15	0.550	S	2.8
0 upto 200	<= 20	0.700	B,H	0.7
	<= 40	0.700		
	<= 100	0.900		
	<= 150	1.150		
	<= 200	1.250		
	> 200	1.250		

Tower calculation

Tropical load case : 3

Factor of correction referring to:
Weight of suspension tower : 1.00
Weight of tension tower : 1.00

Calculation of foundation

Factor of correction referring to:
Leg member force) Suspension tower : 1.00
) Tension tower : 1.00
Concrete volume foundation : 1.00

	132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Tonne/ 6

Basic data for electrical calculation - input

Nominal voltage	:	130	KV
Ambient temperature	:	40.00	°C
Perm.max.temperature conductor	:	75.00	°C
Maximum conductor temperature at short circuit current	:	160.00	°C
Wind velocity	:	0.00	m/s
Hight of line above sea level	:	1000.00	m
Degree of latitude	:	23.50	°
Current density	:	1.01	A/mm²
Cos phi at line end	:	0.90	
Frequency	:	50.00	Hz
Addition to conductors capacity due to towers	:	1.04	p.u.

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	132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Tonne/ 7

Specific investment data - input

Delivery of material

Galv.lattice steel construct.	:	3000.00	DM/t
Pad & chimney foundations	:	400.00	DM/m^3
Conductors	:	2300.00	DM/t
Earth wires	:	2300.00	DM/t
Suspension strings	:	912.69	DM/string
Tension strings	:	1216.92	DM/string
Bundled conductor spacers	:	0.00	DM/Set
Antivibration devices	:	400.00	DM/string
Earth wire accessories	:	120.00	DM/Set
Earthing material	:	881.52	DM/tower
Small parts	:	705.21	DM/tower
Correction factor C1 for strings up to small parts	:	1.00	
CIF-Costs-factor	:	1.05	

Erection of line

Tower erection	:	27.72	h/t
Foundation erection	:	5.46	h/m^3
Stringing of conductors	:	337.76	h/kmcircuit
Stringing of earthwires	:	154.95	h/km
Earthing work on towers	:	10.00	h/tower
Small parts erection	:	10.00	h/tower
Transportation	:	5.00	h/t
Supervision)related to	:	0.05	p.u.
Planing)erection hours	:	0.03	p.u.
Man costs/h inclus.equipment	:	70.00	DM/h
Engineering costs per hour	:	120.00	DM/h

Profile factors

Relation suspens./tens.towers	:	6.00	T/A
Average span length	:	288.00	m
Average extension of towers	:	1.00	m/tower
Profile difficulties fact.C2	:	1.00	

Estates and right of way costs

Costs of tower estates	:	0.00	DM/m²
Costs of right of way	:	0.00	DM/m²

Working tensile stresses and sags - results

Line name : 132 KV - Db.circt line SRI LA3 Opt 1
Normal span length: 320.00 m
Conductor name : 240/40 - Al/St

EDS : 18.00 % of nom. break. load
Average stress : 56.00 N/mm²
Perm.max.tens.str.: 120.00 N/mm²
Longterm tens.str.: 208.00 N/mm²

Load case acc. VDE 0210	Additional load	Conductor temperature TS °C		Tensile stress at TS N/mm²	Support tensile stress N/mm²	Sag at TS m
4.1.2.3	without(EDS)	T1	20.00	55.09	------	8.11
4.3.1 4.3.2	without	T2	75.00	44.56	------	10.03
4.1.2.1 8.1.2.1	Wind 1.00-fold	T5	5.00	77.59	79.18	8.13
Exceptional wind load case	2.00-fold	T5	5.00	109.89	112.68	9.07

Cond.angle of deviation : 44.92 Degree
String angle of deviation: 39.64 Degree

Moments and forces at towers - results and foundations

Towers

Normal moment suspension tower : 828.28 kNm
Normal moment tension tower : 1924.94 kNm

Foundation

Leg member force suspension tower: 56.94 kN
Leg member force tension tower : 147.31 kN

	132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Tonne/10

Electrical data of the high voltage power line - results
selected main data related to the nominal voltage

		Circuit I/II,(III/IV)	
Nominal Voltage	:	130	KV
Line characts.Resistance R1	:	0.13	Ohm/km
Induct.Reactance X1	:	0.40	Ohm/km
Capacitance C1	:	9.61	nF/km
Surge impedance Z	:	362.92	Ohm
Max.voltage gradient at (sub-)conductor surface	:	11.89	KV/cm
Radio interference level acc.to CISPER	:	30.34	dB
Noise level			
dry	:	32.54	dB(A)
wet	:	42.54	dB(A)
Thermal current rating at 40/75oC and 0.00m/s Wind	:	122.26	A/conductor
Surge impedance load	:	46.57	MW/circuit
Max.thermal load rating	:	27.53	MVA/circuit
	:	55.06	MVA/line
Load rating at 1.01 A/mm²	:	55.27	MVA/circuit
Ohmic losses at	:	23.23	kW/km circuit
1.01 A/mm²	:	0.04	%/km
Capacitive load	:	51.00	kVar/km circuit
Short circuit current-rating			
(Bundled-)conductor	:	17.62	kA
Earthwire(s)	:	16.74	kA
Voltage drop and	:	0.0944	%/km
Voltage distorsion at 1.01 A/mm² and cos Phi = 0.90	:	0.0010	degree/km

	132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Tonne/11

Estimated investment costs per km power line - results

Power line data:

Number of circuits	:	2
Number of subconductors	:	1
Name of conductor	:	240/40 - Al/St
Average span length	:	288.00 m
Tower shape	:	Tonne
Tower type	:	S

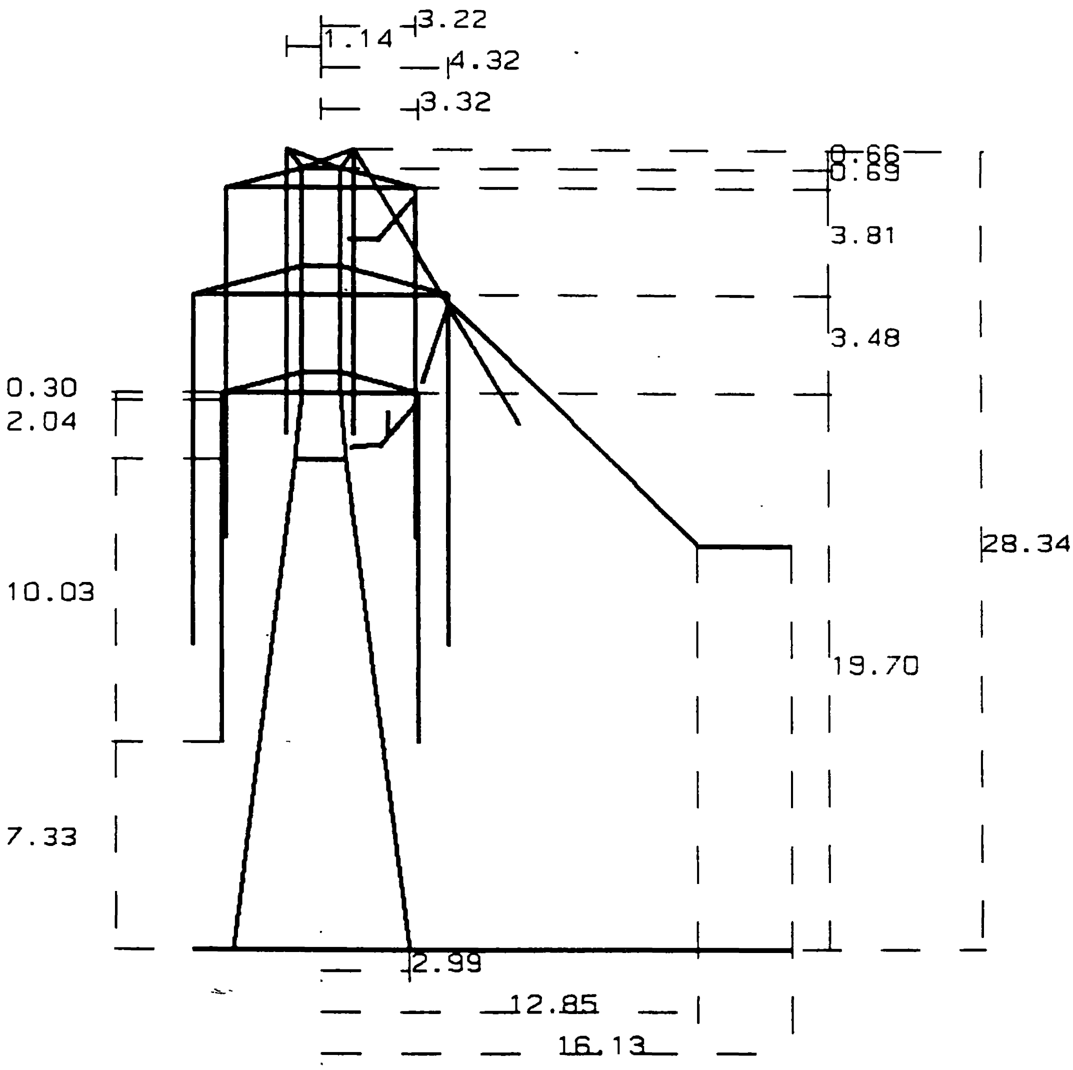
Investment costs :

Material costs cif	:	97330.12 DM/km
Erection costs	:	106518.93 DM/km
Transport costs	:	7015.37 DM/km
Supervision and planning	:	15570.42 DM/km
Tower estate area costs	:	0.00 DM/km
Right of way costs	:	0.00 DM/km
Total investment costs	:	**226434.83 DM/km**

	132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Tonne/12

Calculation of quantities per km power line - results related to the average span length and extension of towers

Weight suspension tower	:	3.74	t
Weight tension tower 160 o	:	4.26	t
Concrete volume foundation			
Suspension tower	:	4.34	m^3
Tension tower	:	10.90	m^3
kilometrical tower weight	:	13.23	t /km
kilometrical concrete volume	:	18.32	m^3/km
kilometrical conductor weight	:	6.03	t /km
kilometrical earth wire weight	:	0.78	t /km
Number of suspension strings	:	17.86	str/km
Number of tension strings	:	5.95	str/km
Number of spacers	:	0.00	set/km
Antivibration device	:	0.00	set/km
Earth wire device	:	7.94	set/km
Tower foot earthing device	:	3.47	set/km
Different small parts	:	3.47	set/km
Right of way	:	32.24	m
Tower base area per km	:	221.23	m^2/km
Area of right of way per km	:	26161.81	m^2/km


1.14
3.22
4.32
3.32
0.66
0.69
3.81
3.48
0.30
2.04
10.03
28.34
19.70
7.33
2.99
12.85
16.13

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Annex-8C.2

T.L. Calculation Sheet for Option 1 (single cct.)

ANNEX-8C.2

	132 kV TRANSMISSION LINE KUKULE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 14. 2.1992 Annex: DREIECK/ 1

O V E R H E A D   P O W E R   L I N E

According to DIN VDE 0210 or equivalent standards

- Calculation of its characteristics -

Basic data

Name of the line : 132 KV - Single circuit line SRI LA2

Highest voltage of line	:	145 KV
Normal span length	:	350 m
Number of subconductors	:	1
Distance of subconductors	:	0 mm
Number of earth wires	:	1
Name of conductor	:	240/40 - Al/St
Name of earthwire	:	95/15 - Al/St
Tower shape	:	Dreieck
Tower type	:	S
Foundation type	:	A
Insulator type	:	L
Climatic zone	:	T

Index explanations :

Tower type	S	:	Lattice steel towers
Foundation type	A	:	Pad & chimney foundation, concreted to undisturbed soil
	S	:	Pad & chimney foundation, concreted to shuttering
Insulator type	L	:	Longrod insulators
	K	:	Cap and pin type insulators
Climatic zone	E	:	Ice loading area
	T	:	Tropical area

Calculated by: LAHMEYER INTERNATIONAL
Consulting Engineers
Head Office
D-6000 Frankfurt(Main)71

Programm Nr.: 0105010E

Technical data conductors - input

Name of conductor	:	240/40 - Al/St	
Relation of cross section	:	6	
Standart	:	DIN48204	
Total cross section	:	282.50	mm^2
Conductive cross section	:	243.05	mm^2
Conductor diameter	:	21.80	mm
Wire dia. outer layer	:	3.45	mm
Total weight	:	0.9850	kg/m
Nominal breaking load	:	86460.00	N
Ohmic resistance	:	0.119	Ohm/km
Resistivity	:	0.029	$Ohm*mm^2/m$
Cont.current carrying cap. at 35/80°C u. 0.6 m/s Wind velocity	:	645.00	A
Permissbl.max.work.stress	:	120.00	N/mm^2
Average tensile stress	:	56.00	N/mm^2
Ult.long term tens.stress	:	208.00	N/mm^2
Effect. mod.of elasticity	:	7.700E+04	N/mm^2
Coeff.of thermal expansion	:	1.890E-05	1/K

Round conductor

	132 kV TRANSMISSION LINE KUKULE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 14. 2.1992 Annex: DREIECK/ 3

Techn.data for calcul.of conduct.tensile stresses and sags-input

Every day stress : 18.00 % of nominal breaking load
15% - 18% without antivibration device
>18% - 21.5% with antivibration device

Conductor temperatures oC

T1 (EDS):	20.00	T2(high) :	60.00	T3 :	0.01
T4(Ice) :	-5.00	T5(low) :	5.00		

Factor of vertical additional load :	1.00
Factor of horizontal additional load:	1.20
Wind load fact.long term tens.load :	2.00

Dynamic wind pressure and aerodynamical drag coeff.acc.VDE 0210

Hight of the power line above ground m	Height of the suspens.point above ground m	Dynamic wind pressure q N/m²	Conductor diamet.d mm	Drag coeff. cf
0 bis 20	<= 15	440	<= 12.50	1.20
0 bis 200	<= 20	530	<= 15.80	1.10
	<= 40	530	> 15.80	1.00
	<= 100	680		
	<= 150	860	no round conduct.	1.30
	<= 200	950		
	> 200	950		

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Basic data for tower shape construction - input

Name of tower shape	:	Dreieck	
Tower shape index	:	B	
Width increasing index 1)	:	G	
Upper part tower body	:	5.00	
Lower part tower body	:	7.00	
Crossarm tie incline	:	15.00	Degree
Length difference of crossarm,	:	0.10	m
Length of step bolts	:	0.20	m
String length;	:	2.04	m
Heigth of metalparts string	:	0.40	m
VDE-clearance conduct.-ground,	:	6.23	m
Additional ground clearance	:	0.10	m
Projection protect.fittings	:	0.00	m
Projection accessories;	:	0.05	m
Lightning protection angle of earth wire	:	30.00	Degree
Additional crossarm length	:	0.20	m
Heigth of susp.swivel clevis or V-links	:	0.30	m
Additional tower height	:	0.30	m
Width of towerbody at top	:	1.31	m
VDE-Minimum clearance	:	0.93	m

Footnote:
1) Width increasing indices
G in Degree (Inclining of one leg member)
M in mm/m (in relation to half width of tower body)

	132 kV TRANSMISSION LINE KUKULE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 14. 2.1992 Annex: DREIECK/ 5

Basic data for estimation towers a.foundation - input

Dynamic wind pressure and aerodynamical drag coefficient acc. VDE 0210 for towers, crossarms and insulators

Hight of the power line above ground m	Hight of the components above ground m	Dynamic wind pressure q KN/m²	Towertype	Drag coeff. cf
0 upto 20	<= 15	0.550	S	2.8
0 upto 200	<= 20	0.700	B,H	0.7
	<= 40	0.700		
	<= 100	0.900		
	<= 150	1.150		
	<= 200	1.250		
	> 200	1.250		

Tower calculation

Tropical load case : 3

Factor of correction referring to:
Weight of suspension tower : 1.00
Weight of tension tower : 1.00

Calculation of foundation

Factor of correction referring to:
Leg member force) Suspension tower : 1.00
) Tension tower : 1.00
Concrete volume foundation : 1.00

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132 kV TRANSMISSION LINE KUKULE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 14. 2.1992 Annex: DREIECK/ 6

Basic data for electrical calculation - input

Nominal voltage	:	130	KV
Ambient temperature	:	35.00	°C
Perm.max.temperature conductor	:	60.00	°C
Maximum conductor temperature at short circuit current	:	160.00	°C
Wind velocity	:	0.60	m/s
Hight of line above sea level	:	1000.00	m
Degree of latitude	:	1.00	°
Current density	:	1.00	A/mm^2
Cos phi at line end	:	0.98	
Frequency	:	50.00	Hz
Addition to conductors capacity due to towers	:	1.04	p.u.

	132 kV TRANSMISSION LINE KUKULE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 14. 2.1992 Annex: DREIECK/ 7

Specific investment data - input

Delivery of material

Galv.lattice steel construct.:	3000.00	DM/t
Pad & chimney foundations :	400.00	DM/m^3
Conductors :	2300.00	DM/t
Earth wires :	2300.00	DM/t
Suspension strings :	912.69	DM/string
Tension strings :	1216.92	DM/string
Bundled conductor spacers :	40.00	DM/Set
Antivibration devices :	400.00	DM/string
Earth wire accessories :	120.00	DM/Set
Earthing material :	881.52	DM/tower
Small parts :	705.21	DM/tower
Correction factor C1 for strings up to small parts :	1.00	
CIF-Costs-factor :	1.05	

Erection of line

Tower erection :	27.72	h/t
Foundation erection :	5.46	h/m^3
Stringing of conductors :	337.76	h/kmcircuit
Stringing of earthwires :	88.99	h/km
Earthing work on towers :	10.00	h/tower
Small parts erection :	10.00	h/tower
Transportation :	5.00	h/t
Supervision)related to :	0.05	p.u.
Planing)erection hours :	0.03	p.u.
Man costs/h inclus.equipment :	70.00	DM/h
Engineering costs per hour :	120.00	DM/h

Profile factors

Relation suspens./tens.towers:	6.00	T/A
Average span length :	315.00	m
Average extension of towers :	0.00	m/tower
Profile difficulties fact.C2 :	1.00	

Estates and right of way costs

Costs of tower estates :	0.00	DM/m²
Costs of right of way :	0.00	DM/m²

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Working tensile stresses and sags - results

Line name : 132 KV - Single circuit line SRI LA2
Normal span length: 350.00 m
Conductor name : 240/40 - Al/St

EDS : 18.00 % of nom. break. load
Average stress : 56.00 N/mm²
Perm.max.tens.str.: 120.00 N/mm²
Longterm tens.str.: 208.00 N/mm²

Load case acc. VDE 0210	Additional load		Conductor temperature TS °C	Tensile stress at TS N/mm²	Support tensile stress N/mm²	Sag at TS m
4.1.2.3	without(EDS)	T1	20.00	55.09	------	9.70
4.3.1 4.3.2	without	T2	60.00	47.88	------	11.17
4.1.2.1 8.1.2.1	Wind 1.20-fold	T5	5.00	83.04	85.13	9.89
Exceptional wind load case	2.00-fold	T5	5.00	122.98	126.82	11.03

Cond.angle of deviation : 49.39 Degree
String angle of deviation: 43.69 Degree

	132 kV TRANSMISSION LINE KUKULE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 14. 2.1992 Annex: DREIECK/ 9

Moments and forces at towers - results and foundations

Towers

Normal moment suspension tower	:	715.76	kNm
Normal moment tension tower	:	1107.17	kNm

Foundation

Leg member force suspension tower	:	49.56	kN
Leg member force tension tower	:	83.84	kN

	132 kV TRANSMISSION LINE KUKULE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 14. 2.1992 Annex: DREIECK/10

Electrical data of the high voltage power line - results
selected main data related to the nominal voltage

		Circuit I/II,(III/IV)	
Nominal Voltage	:	130	KV
Line characts.Resistance R1	:	0.13	Ohm/km
Induct.Reactance X1	:	0.41	Ohm/km
Capacitance C1	:	9.26	nF/km
Surge impedance Z	:	375.35	Ohm
Max.voltage gradient at (sub-)conductor surface	:	11.46	KV/cm
Radio interference level acc.to CISPER	:	24.43	dB
Noise level			
dry	:	24.88	dB(A)
wet	:	34.88	dB(A)
Thermal current rating at 35/60oC and 0.60m/s Wind	:	434.70	A/conductor
Surge impedance load	:	45.02	MW/circuit
Max.thermal load rating	:	97.88	MVA/circuit
	:	97.88	MVA/line
Load rating at 1.00 A/mm²	:	54.73	MVA/circuit
Ohmic losses at	:	22.32	kW/km circuit
1.00 A/mm²	:	0.04	%/km
Capacitive load	:	49.16	kVar/km circuit
Short circuit current-rating			
(Bundled-)conductor	:	19.34	kA
Earthwire(s)	:	8.58	kA
Voltage drop	:	0.0663	%/km
and			
Voltage distorsion at 1.00 A/mm² and cos Phi = 0.98	:	0.0012	degree/km

	132 kV TRANSMISSION LINE KUKULE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 14. 2.1992 Annex: DREIECK/11

Estimated investment costs per km power line - results

Power line data:

Number of circuits	:	1
Number of subconductors	:	1
Name of conductor	:	240/40 - Al/St
Average span length	:	315.00 m
Tower shape	:	Dreieck
Tower type	:	S

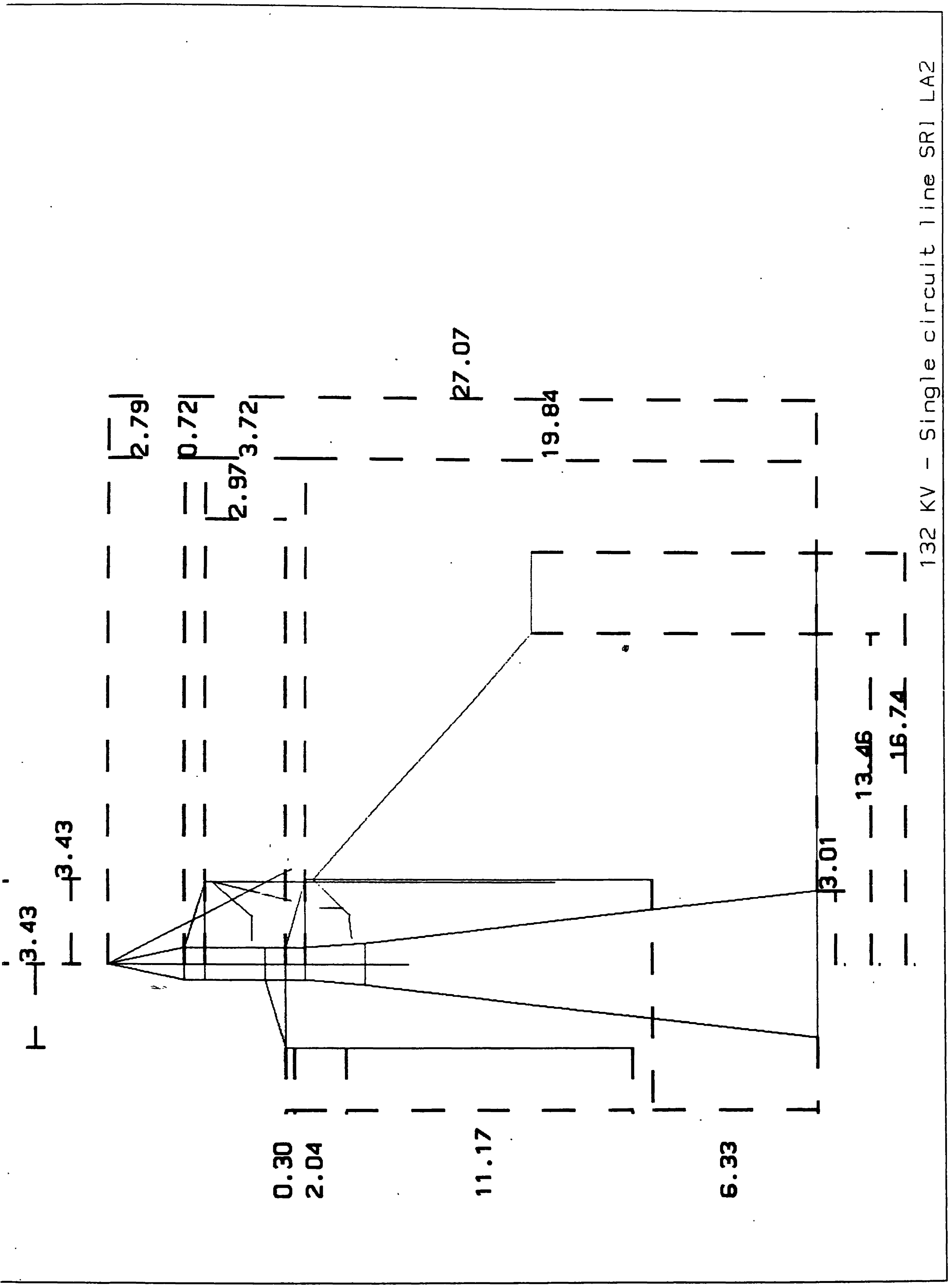
Investment costs :

Material costs cif	:	63445.19 DM/km
Erection costs	:	59461.79 DM/km
Transport costs	:	4817.63 DM/km
Supervision and planning	:	8815.46 DM/km
Tower estate area costs	:	0.00 DM/km
Right of way costs	:	0.00 DM/km
Total investment costs	:	**136540.06 DM/km**

	132 kV TRANSMISSION LINE KUKULE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 14. 2.1992 Annex: DREIECK/12

Calculation of quantities per km power line - results related to the average span length and extension of towers

Weight suspension tower	:	3.37	t
Weight tension tower 160 o	:	2.65	t
Concrete volume foundation			
Suspension tower	:	3.80	m^3
Tension tower	:	6.29	m^3
kilometrical tower weight	:	10.40	t /km
kilometrical concrete volume	:	13.06	m^3/km
kilometrical conductor weight	:	3.01	t /km
kilometrical earth wire weight	:	0.39	t /km
Number of suspension strings	:	8.33	str/km
Number of tension strings	:	2.38	str/km
Number of spacers	:	0.00	set/km
Antivibration device	:	0.00	set/km
Earth wire device	:	3.57	set/km
Tower foot earthing device	:	3.17	set/km
Different small parts	:	3.17	set/km
Right of way	:	33.48	m
Tower base area per km	:	204.01	m^2/km
Area of right of way per km	:	25857.88	m^2/km


132 KV - Single circuit line SRI LA2
3.43
3.43
2.79
0.72
3.72
2.97
27.07
19.84
13.46
16.74
3.01
0.30
2.04
11.17
6.33

Annex-8C.3

T.L. Calculation Sheet for Option 2 & 3 (double cct.)

	132 kV TRANSMISSION LINE KUKULE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Tonne/ 1

O V E R H E A D   P O W E R   L I N E

According to DIN VDE 0210 or equivalent standards

\- Calculation of its characteristics -

Basic data

Name of the line : 132 KV - Db.circt line SRI LA3 Opt 2/3

Highest voltage of line	:	145 KV
Normal span length	:	320 m
Number of subconductors	:	1
Distance of subconductors	:	0 mm
Number of earth wires	:	2
Name of conductor	:	300/50 - Al/St
Name of earthwire	:	95/15 - Al/St
Tower shape	:	Tonne
Tower type	:	S
Foundation type	:	A
Insulator type	:	L
Climatic zone	:	T

Index explanations :

Tower type	S	:	Lattice steel towers
Foundation type	A	:	Pad & chimney foundation, concreted to undisturbed soil
	S	:	Pad & chimney foundation, concreted to shuttering
Insulator type	L	:	Longrod insulators
	K	:	Cap and pin type insulators
Climatic zone	E	:	Ice loading area
	T	:	Tropical area

Calculated by: LAHMEYER INTERNATIONAL
Consulting Engineers
Head Office
D-6000 Frankfurt(Main)71

Programm Nr.: 0105010E

Technical data conductors - input

Name of conductor	:	300/50 - Al/St	
Relation of cross section	:	6	
Standart	:	DIN48204	
Total cross section	:	353.70	mm^2
Conductive cross section	:	304.26	mm^2
Conductor diameter	:	24.50	mm
Wire dia. outer layer	:	3.86	mm
Total weight	:	1.2330	kg/m
Nominal breaking load	:	105090.00	N
Ohmic resistance	:	0.095	Ohm/km
Resistivity	:	0.029	$Ohm*mm^2/m$
Cont.current carrying cap. at 35/80°C u. 0.6 m/s Wind velocity	:	740.00	A
Permissbl.max.work.stress	:	120.00	N/mm^2
Average tensile stress	:	56.00	N/mm^2
Ult.long term tens.stress	:	208.00	N/mm^2
Effect. mod.of elasticity	:	7.700E+04	N/mm^2
Coeff.of thermal expansion	:	1.890E-05	1/K
Round conductor			

Techn.data for calcul.of conduct.tensile stresses and sags-input

Every day stress : 18.00 % of nominal breaking load
15% - 18% without antivibration device
>18% - 21.5% with antivibration device

Conductor temperatures oC

T1 (EDS):	20.00	T2(high) :	80.00	T3 :	0.01
T4(Ice) :	-5.00	T5(low) :	5.00		

Factor of vertical additional load :	1.00
Factor of horizontal additional load:	1.00
Wind load fact.long term tens.load :	2.00

Dynamic wind pressure and aerodynamical drag coeff.acc.VDE 0210

Hight of the power line above ground m	Height of the suspens.point above ground m	Dynamic wind pressure q N/m²	Conductor diamet.d mm	Drag coeff. cf
0 bis 20	<= 15	440	<= 12.50	1.20
0 bis 200	<= 20	530	<= 15.80	1.10
	<= 40	530	> 15.80	1.00
	<= 100	680		
	<= 150	860	no round conduct.	1.30
	<= 200	950		
	> 200	950		

Basic data for tower shape construction - input

Name of tower shape	:	Tonne	
Tower shape index	:	A	
Width increasing index 1)	:	G	
Upper part tower body	:	5.00	
Lower part tower body	:	7.00	
Crossarm tie incline	:	15.00	Degree
Length difference of crossarm,	:	0.10	m
Length of step bolts	:	0.20	m
String length;	:	2.04	m
Heigth of metalparts string	:	0.40	m
VDE-clearance conduct.-ground,	:	6.23	m
Additional ground clearance	:	0.10	m
Projection protect.fittings	:	0.00	m
Projection accessories;	:	0.05	m
Lightning protection angle of earth wire	:	30.00	Degree
Additional cross arm length	:	0.20	m
Heigth of susp.swivel clevis or V-links	:	0.30	m
Additional tower height	:	0.10	m
Width of towerbody at top	:	1.31	m
VDE-Minimum clearance	:	0.93	m

Footnote:
1) Width increasing indices
G in Degree (Inclining of one leg member)
M in mm/m (in relation to half width of tower body)

Basic data for estimation towers a.foundation - input

Dynamic wind pressure and aerodynamical drag coefficient acc. VDE 0210 for towers, crossarms and insulators

Hight of the power line above ground m	Hight of the components above ground m	Dynamic wind pressure q KN/m²	Towertype	Drag coeff. cf
0 upto 20	<= 15	0.550	S	2.8
0 upto 200	<= 20	0.700	B,H	0.7
	<= 40	0.700		
	<= 100	0.900		
	<= 150	1.150		
	<= 200	1.250		
	> 200	1.250		

Tower calculation

Tropical load case : 3

Factor of correction referring to:
- Weight of suspension tower : 1.00
- Weight of tension tower : 1.00

Calculation of foundation

Factor of correction referring to:

Leg member force) Suspension tower : 1.00
) Tension tower : 1.00
Concrete volume foundation : 1.00

	132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Tonne/ 6

Basic data for electrical calculation - input

Nominal voltage	:	130	KV
Ambient temperature	:	40.00	°C
Perm.max.temperature conductor	:	80.00	°C
Maximum conductor temperature at short circuit current	:	160.00	°C
Wind velocity	:	0.00	m/s
Hight of line above sea level	:	1000.00	m
Degree of latitude	:	23.50	°
Current density	:	1.10	A/mm²
Cos phi at line end	:	0.90	
Frequency	:	50.00	Hz
Addition to conductors capacity due to towers	:	1.04	p.u.

	132 kV TRANSMISSION LINE KUKULE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Tonne/ 7

Specific investment data - input

Delivery of material

Galv.lattice steel construct.:	3000.00	DM/t
Pad & chimney foundations :	400.00	DM/m^3
Conductors :	2300.00	DM/t
Earth wires :	2300.00	DM/t
Suspension strings :	1017.78	DM/string
Tension strings :	1357.04	DM/string
Bundled conductor spacers :	0.00	DM/Set
Antivibration devices :	400.00	DM/string
Earth wire accessories :	120.00	DM/Set
Earthing material :	881.52	DM/tower
Small parts :	705.21	DM/tower
Correction factor C1 for strings up to small parts :	1.00	
CIF-Costs-factor :	1.05	

Erection of line

Tower erection :	27.72	h/t
Foundation erection :	5.46	h/m^3
Stringing of conductors :	365.82	h/kmcircuit
Stringing of earthwires :	154.95	h/km
Earthing work on towers :	10.00	h/tower
Small parts erection :	10.00	h/tower
Transportation :	5.00	h/t
Supervision) related to :	0.05	p.u.
Planing) erection hours :	0.03	p.u.
Man costs/h inclus.equipment :	70.00	DM/h
Engineering costs per hour :	120.00	DM/h

Profile factors

Relation suspens./tens.towers:	6.00	T/A
Average span length :	288.00	m
Average extension of towers :	1.00	m/tower
Profile difficulties fact.C2 :	1.00	

Estates and right of way costs

Costs of tower estates :	0.00	DM/m²
Costs of right of way :	0.00	DM/m²

132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Tonne/ 8

Working tensile stresses and sags - results

Line name : 132 KV - Db.circt line SRI LA3 Opt 2
Normal span length: 320.00 m
Conductor name : 300/50 - Al/St

EDS : 18.00 % of nom. break. load
Average stress : 56.00 N/mm²
Perm.max.tens.str.: 120.00 N/mm²
Longterm tens.str.: 208.00 N/mm²

Load case acc. VDE 0210	Additional load		Conductor temperature TS °C	Tensile stress at TS N/mm²	Support tensile stress N/mm²	Sag at TS m
4.1.2.3	without(EDS)	T1	20.00	53.48	------	8.35
4.3.1 4.3.2	without	T2	80.00	42.95	------	10.40
4.1.2.1 8.1.2.1	Wind 1.00-fold	T5	5.00	72.51	74.04	8.27
Exceptional wind load case	2.00-fold	T5	5.00	100.84	103.40	9.08

Cond.angle of deviation : 41.83 Degree
String angle of deviation: 37.19 Degree

	132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Tonne/ 9

Moments and forces at towers - results
and foundations

==

Towers

Normal moment suspension tower : 880.29 kNm
Normal moment tension tower : 2170.79 kNm

Foundation

Leg member force suspension tower: 59.06 kN
Leg member force tension tower : 163.27 kN

	132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Tonne/10

Electrical data of the high voltage power line - results
selected main data related to the nominal voltage

			Circuit I/II,(III/IV)	
Nominal Voltage		:	130	KV
Line characts.Resistance	R1	:	0.10	Ohm/km
Induct.Reactance	X1	:	0.39	Ohm/km
Capacitance	C1	:	9.81	nF/km
Surge impedance	Z	:	355.84	Ohm
Max.voltage gradient at (sub-)conductor surface		:	10.85	KV/cm
Radio interference level acc.to CISPER		:	28.34	dB
Noise level dry		:	30.99	dB(A)
wet		:	40.99	dB(A)
Thermal current rating at 40/80oC and 0.00m/s Wind		:	190.96	A/conductor
Surge impedance load		:	47.86	MW/circuit
Max.thermal load rating		:	43.16	MVA/circuit
		:	86.33	MVA/line
Load rating at 1.10 A/mm²		:	75.65	MVA/circuit
Ohmic losses at		:	34.44	kW/km circuit
1.10 A/mm²		:	0.05	%/km
Capacitive load		:	52.49	kVar/km circuit
Short circuit current-rating (Bundled-)conductor		:	21.31	kA
Earthwire(s)		:	16.74	kA
Voltage drop		:	0.1164	%/km
and Voltage distorsion at 1.10 A/mm² and cos Phi = 0.90		:	0.0014	degree/km

	132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Tonne/11

Estimated investment costs per km power line - results

Power line data:

Number of circuits	:	2
Number of subconductors	:	1
Name of conductor	:	300/50 - Al/St
Average span length	:	288.00 m
Tower shape	:	Tonne
Tower type	:	S

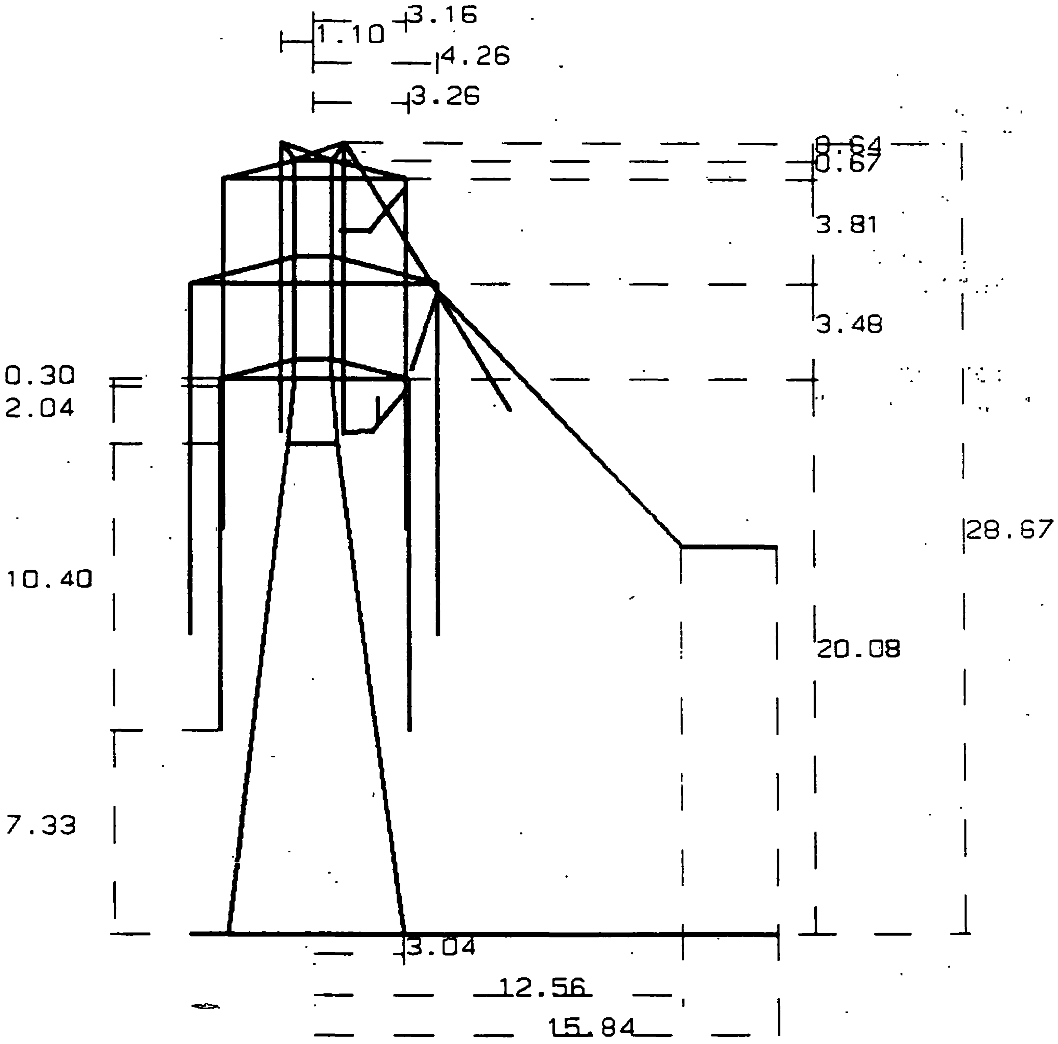
Investment costs :

Material costs cif	:	106561.52 DM/km
Erection costs	:	112249.23 DM/km
Transport costs	:	7800.53 DM/km
Supervision and planning	:	16463.97 DM/km
Tower estate area costs	:	0.00 DM/km
Right of way costs	:	0.00 DM/km
Total investment costs	:	**243075.25 DM/km**

	132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5.3.1992 Annex: Tonne/12

Calculation of quantities per km power line - results related to the average span length and extension of towers

Weight suspension tower	:	3.90	t
Weight tension tower 160 o	:	4.72	t
Concrete volume foundation			
Suspension tower	:	4.49	m^3
Tension tower	:	12.06	m^3
kilometrical tower weight	:	13.96	t /km
kilometrical concrete volume	:	19.35	m^3/km
kilometrical conductor weight	:	7.55	t /km
kilometrical earth wire weight	:	0.78	t /km
Number of suspension strings	:	17.86	str/km
Number of tension strings	:	5.95	str/km
Number of spacers	:	0.00	set/km
Antivibration device	:	0.00	set/km
Earth wire device	:	7.94	set/km
Tower foot earthing device	:	3.47	set/km
Different small parts	:	3.47	set/km
Right of way	:	31.68	m
Tower base area per km	:	226.37	m^2/km
Area of right of way per km	:	25750.29	m^2/km



3.16
1.10
4.26
3.26
0.64
0.67
3.81
3.48
0.30
2.04
10.40
7.33
28.67
20.08
3.04
12.56
15.84

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Annex-8C.4

T.L. Calculation Sheet for Option 2 & 3 (single cct.)

	132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Dreieck/ 1

O V E R H E A D   P O W E R   L I N E

According to DIN VDE 0210 or equivalent standards
- Calculation of its characteristics -

Basic data

Name of the line : 132 KV - Sg.circt line SRI LA2 Opt 2/3

Highest voltage of line	:	145 KV
Normal span length	:	320 m
Number of subconductors	:	1
Distance of subconductors	:	0 mm
Number of earth wires	:	1
Name of conductor	:	300/50 - Al/St
Name of earthwire	:	95/15 - Al/St
Tower shape	:	Dreieck
Tower type	:	S
Foundation type	:	A
Insulator type	:	L
Climatic zone	:	T

Index explanations :

Tower type	S	:	Lattice steel towers
Foundation type	A	:	Pad & chimney foundation, concreted to undisturbed soil
	S	:	Pad & chimney foundation, concreted to shuttering
Insulator type	L	:	Longrod insulators
	K	:	Cap and pin type insulators
Climatic zone	E	:	Ice loading area
	T	:	Tropical area

Calculated by: LAHMEYER INTERNATIONAL
Consulting Engineers
Head Office
D-6000 Frankfurt(Main)71

Programm Nr.: 0105010E

Technical data conductors - input

Name of conductor	:	300/50 - Al/St	
Relation of cross section	:	6	
Standart	:	DIN48204	
Total cross section	:	353.70	mm^2
Conductive cross section	:	304.26	mm^2
Conductor diameter	:	24.50	mm
Wire dia. outer layer	:	3.86	mm
Total weight	:	1.2330	kg/m
Nominal breaking load	:	105090.00	N
Ohmic resistance	:	0.095	Ohm/km
Resistivity	:	0.029	$Ohm*mm^2/m$
Cont.current carrying cap. at 35/80°C u. 0.6 m/s Wind velocity	:	740.00	A
Permissbl.max.work.stress	:	120.00	N/mm^2
Average tensile stress	:	56.00	N/mm^2
Ult.long term tens.stress	:	208.00	N/mm^2
Effect. mod.of elasticity	:	7.700E+04	N/mm^2
Coeff.of thermal expansion	:	1.890E-05	1/K

Round conductor

Techn.data for calcul.of conduct.tensile stresses and sags-input

Every day stress :	18.00 %	of nominal breaking load
	15% - 18%	without antivibration device
	>18% - 21.5%	with antivibration device

Conductor temperatures oC

T1 (EDS):	20.00	T2(high) :	80.00	T3 :	0.01
T4(Ice) :	-5.00	T5(low) :	5.00		

Factor of vertical additional load :	1.00
Factor of horizontal additional load:	1.20
Wind load fact.long term tens.load :	2.00

Dynamic wind pressure and aerodynamical drag coeff.acc.VDE 0210

Hight of the power line above ground m	Height of the suspens.point above ground m	Dynamic wind pressure q N/m²	Conductor diamet.d mm	Drag coeff. cf
0 bis 20	<= 15	440	<= 12.50	1.20
0 bis 200	<= 20	530	<= 15.80	1.10
	<= 40	530	> 15.80	1.00
	<= 100	680		
	<= 150	860	no round conduct.	1.30
	<= 200	950		
	> 200	950		

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	132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Dreieck/ 4

Basic data for tower shape construction - input

Name of tower shape	:	Dreieck	
Tower shape index	:	B	
Width increasing index 1)	:	G	
Upper part tower body	:	5.00	
Lower part tower body	:	7.00	
Crossarm tie incline	:	15.00	Degree
Length difference of crossarm,	:	0.10	m
Length of step bolts	:	0.20	m
String length;	:	2.04	m
Heigth of metalparts string	:	0.40	m
VDE-clearance conduct.-ground,	:	6.23	m
Additional ground clearance	:	0.10	m
Projection protect.fittings	:	0.00	m
Projection accessories;	:	0.05	m
Lightning protection angle of earth wire	:	30.00	Degree
Additional cross arm length	:	0.20	m
Heigth of susp.swivel clevis or V-links	:	0.30	m
Additional tower height	:	0.10	m
Width of towerbody at top	:	1.31	m
VDE-Minimum clearance	:	0.93	m

Footnote:
1) Width increasing indices
G in Degree (Inclining of one leg member)
M in mm/m (in relation to half width of tower body)

	132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Dreieck/ 5

Basic data for estimation towers a. foundation - input

Dynamic wind pressure and aerodynamical drag coefficient acc. VDE 0210 for towers, crossarms and insulators

Hight of the power line above ground m	Hight of the components above ground m	Dynamic wind pressure q KN/m²	Towertype	Drag coeff. cf
0 upto 20	<= 15	0.550	S	2.8
0 upto 200	<= 20	0.700	B,H	0.7
	<= 40	0.700		
	<= 100	0.900		
	<= 150	1.150		
	<= 200	1.250		
	> 200	1.250		

Tower calculation

Tropical load case : 3

Factor of correction referring to:
Weight of suspension tower : 1.00
Weight of tension tower : 1.00

Calculation of foundation

Factor of correction referring to:
Leg member force) Suspension tower : 1.00
) Tension tower : 1.00
Concrete volume foundation : 1.00

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132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Dreieck/ 6

Basic data for electrical calculation - input

Nominal voltage	:	130	KV
Ambient temperature	:	40.00	°C
Perm.max.temperature conductor	:	80.00	°C
Maximum conductor temperature at short circuit current	:	160.00	°C
Wind velocity	:	0.00	m/s
Hight of line above sea level	:	1000.00	m
Degree of latitude	:	23.50	°
Current density	:	1.10	A/mm²
Cos phi at line end	:	0.90	
Frequency	:	50.00	Hz
Addition to conductors capacity due to towers	:	1.04	p.u.

	132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Dreieck/ 7

Specific investment data input

Delivery of material

Galv.lattice steel construct.	:	3000.00	DM/t
Pad & chimney foundations	:	400.00	DM/m^3
Conductors	:	2300.00	DM/t
Earth wires	:	2300.00	DM/t
Suspension strings	:	1017.78	DM/string
Tension strings	:	1357.04	DM/string
Bundled conductor spacers	:	40.00	DM/Set
Antivibration devices	:	400.00	DM/string
Earth wire accessories	:	120.00	DM/Set
Earthing material	:	881.52	DM/tower
Small parts	:	705.21	DM/tower
Correction factor C1 for strings up to small parts	:	1.00	
CIF-Costs-factor	:	1.05	

Erection of line

Tower erection	:	27.72	h/t
Foundation erection	:	5.46	h/m^3
Stringing of conductors	:	365.82	h/kmcircuit
Stringing of earthwires	:	88.99	h/km
Earthing work on towers	:	10.00	h/tower
Small parts erection	:	10.00	h/tower
Transportation	:	5.00	h/t
Supervision)related to	:	0.05	p.u.
Planing)erection hours	:	0.03	p.u.
Man costs/h inclus.equipment	:	70.00	DM/h
Engineering costs per hour	:	120.00	DM/h

Profile factors

Relation suspens./tens.towers	:	6.00	T/A
Average span length	:	288.00	m
Average extension of towers	:	0.00	m/tower
Profile difficulties fact.C2	:	1.00	

Estates and right of way costs

Costs of tower estates	:	0.00	DM/m²
Costs of right of way	:	0.00	DM/m²

	132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Tonne/ 8

Working tensile stresses and sags - results

Line name : 132 KV - Sg.circt line SRI LA2 Opt 2
Normal span length: 320.00 m
Conductor name : 300/50 - Al/St

EDS : 18.00 % of nom. break. load
Average stress : 56.00 N/mm²
Perm.max.tens.str.: 120.00 N/mm²
Longterm tens.str.: 208.00 N/mm²

Load case acc. VDE 0210	Additional load		Conductor temperature TS °C	Tensile stress at TS N/mm²	Support tensile stress N/mm²	Sag at TS m
4.1.2.3	without(EDS)	T1	20.00	53.48	------	8.35
4.3.1 4.3.2	without	T2	80.00	42.95	------	10.40
4.1.2.1 8.1.2.1	Wind 1.20-fold	T5	5.00	77.80	79.50	8.43
Exceptional wind load case2.00-fold		T5	5.00	112.59	115.65	9.40

Cond.angle of deviation : 47.05 Degree
String angle of deviation: 41.32 Degree

	132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Tonne/ 9

Moments and forces at towers - results and foundations

Towers

Normal moment suspension tower	:	678.39	kNm
Normal moment tension tower	:	1093.60	kNm

Foundation

Leg member force suspension tower	:	48.34	kN
Leg member force tension tower	:	85.46	kN

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132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Tonne/10

Electrical data of the high voltage power line - results
selected main data related to the nominal voltage

		Circuit I/II,(III/IV)	
Nominal Voltage	:	130	KV
Line characts.Resistance R1	:	0.10	Ohm/km
Induct.Reactance X1	:	0.40	Ohm/km
Capacitance C1	:	9.50	nF/km
Surge impedance Z	:	366.67	Ohm
Max.voltage gradient at (sub-)conductor surface	:	10.46	KV/cm
Radio interference level acc.to CISPER	:	22.57	dB
Noise level			
dry	:	23.46	dB(A)
wet	:	33.46	dB(A)
Thermal current rating at 40/80oC and 0.00m/s Wind	:	190.96	A/conductor
Surge impedance load	:	46.09	MW/circuit
Max.thermal load rating	:	43.00	MVA/circuit
	:	43.00	MVA/line
Load rating at 1.10 A/mm²	:	75.36	MVA/circuit
Ohmic losses at	:	34.44	kW/km circuit
1.10 A/mm²	:	0.05	%/km
Capacitive load	:	50.43	kVar/km circuit
Short circuit current-rating			
(Bundled-)conductor	:	21.31	kA
Earthwire(s)	:	8.37	kA
Voltage drop	:	0.1190	%/km
and			
Voltage distorsion at 1.10 A/mm² and cos Phi = 0.90	:	0.0014	degree/km

132 kV TRANSMISSION LINE KUKULKE - MATUGAMA SRI LANKA	Order: ZICKMAN Date : 5. 3.1992 Annex: Tonne/11

Estimated investment costs per km power line - results

Power line data:

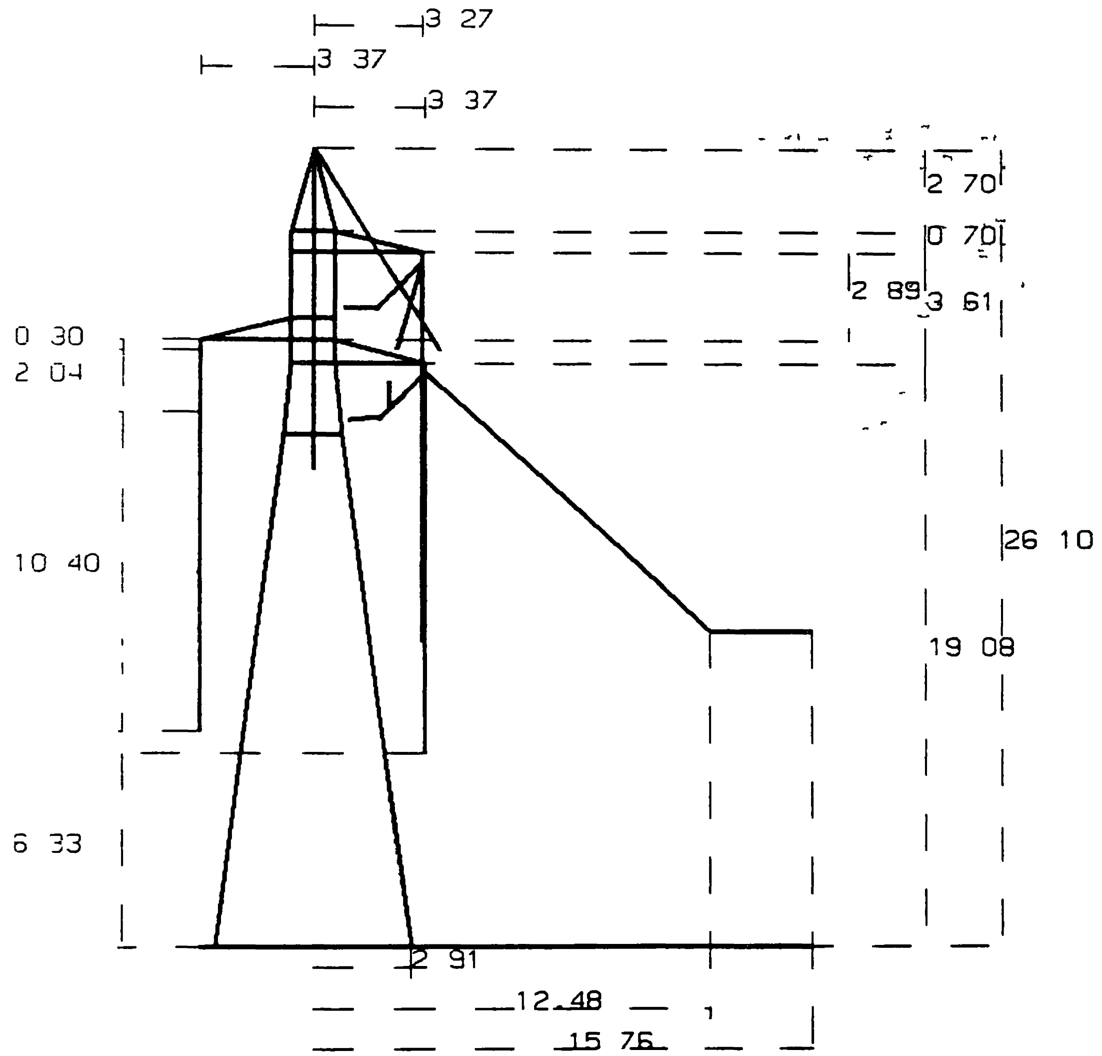
Number of circuits	:	1
Number of subconductors	:	1
Name of conductor	:	300/50 - Al/St
Average span length	:	288.00 m
Tower shape	:	Dreieck
Tower type	:	S

Investment costs :

Material costs cif	:	70558.74 DM/km
Erection costs	:	63361.23 DM/km
Transport costs	:	5286.20 DM/km
Supervision and planning	:	9414.51 DM/km
Tower estate area costs	:	0.00 DM/km
Right of way costs	:	0.00 DM/km
Total investment costs	:	**148620.68 DM/km**

Calculation of quantities per km power line - results related to the average span length and extension of towers

Weight suspension tower	:	3.24	t
Weight tension tower 160 o	:	2.62	t
Concrete volume foundation			
Suspension tower	:	3.71	m^3
Tension tower	:	6.41	m^3
kilometrical tower weight	:	10.94	t /km
kilometrical concrete volume	:	14.23	m^3/km
kilometrical conductor weight	:	3.77	t /km
kilometrical earth wire weight	:	0.39	t /km
Number of suspension strings	:	8.93	str/km
Number of tension strings	:	2.98	str/km
Number of spacers	:	0.00	set/km
Antivibration device	:	0.00	set/km
Earth wire device	:	3.97	set/km
Tower foot earthing device	:	3.47	set/km
Different small parts	:	3.47	set/km
Right of way	:	31.52	m
Tower base area per km	:	212.81	m^2/km
Area of right of way per km	:	24778.86	m^2/km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Annex-8C.5

Proposal for Tender Documents and Erection Phase

ANNEX-8C.5

TECHNICAL SPECIFICATIONS

COMMON TECHNICAL SPECIFICATION

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TECHNICAL SPECIFICATION

DESCRIPTION OF 132 KV LINE

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3 Design
3.1 Design Spans
3.2 Design Loads
3.3 Standards
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4.4 Design
4.5 Construction
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4 7 Conductor and Earthwire Attachments
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4 9 Workmanship
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5 Insulators and Fittings
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5.5 Metal Components
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5.7 Insulator Fittings
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I2 Footing and Galvernizing Tests
I3 Tests on Completion

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