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DEVELOPING BENCHMARKS OF CAPITAL COST – MODEL FOR BENCHMARKING CAPITAL COST OF TRANSMISSION LINES

EXPLANATORY MEMORANDUM

1.0 INTRODUCTION

1.1 The Tariff Policy notified by the Central Government on 6th January, 2006 under Section 3 of the Electricity Act, 2003 provides that when allowing the total capital cost of the project, the Appropriate Commission would ensure that these are reasonable and to achieve this objective, requisite benchmarks on capital costs should be evolved by the Regulatory Commissions.

1.2 While framing the Terms and Conditions of Tariff for 2009-14, it was inter-alia, noted as under:

- In a cost based regulation capital cost of the project is perhaps the most important parameter. The capital cost on the completion of the project is the starting point as the rate base for deciding the return on the investment made by the generators. Different philosophies and practices have been followed "

- Prior to 1992 and during the period 1992 to 1997 and 1997 to 2001, the capital cost of the project used to be based on gross book value as per the audited accounts. The changes in the capital cost by the way of capitalization and FERV were also being accounted for and tariff was being adjusted retrospectively. This practice has been followed even during the tariff period 2004-09."

- While admitting the projected capital expenditure as on COD, prudence check of capital cost shall be carried out based on the applicable benchmark norms to be published separately by the Commission from time to time. This is in line with Tariff Policy. The Commission has already initiated the process for evolving benchmarks for transmission projects................."

1.3 Central; Electricity Regulatory Commission (Terms and Conditions of Tariff) Regulations, 2009 applicable for the period 1.4.2009 to 31.3.2014 were notified by the Commission on 19th January, 2009.

Sub-clause (2) of Clause 7 of the above regulations provides that subject to prudence check by the Commission, the capital cost shall form the basis for determination of tariff provided that prudence check of capital cost may be carried out based on the benchmark norms to be published separately by the Commission from time to time:

2.0 INITIATION OF BENCHMARKING PROCESS

2.1 Central Electricity Regulatory Commission (CERC) initiated the process in June 2008 in this regard.

2.2 The work of Developing Bench Marks of Capital Cost for Transmission System Elements (Transmission Lines) was awarded to a Consortium of consultants in September, 2008.

3.0 OBJECTIVES, SCOPE OF WORK AND DELIVERABLES

3.1 Objectives

(i) Developing benchmarks of capital cost for Transmission Lines by analyzing all India data for this purpose.

(ii) Recommending appropriate methodology through which a bench mark cost of a completed project would be arrived at for the purpose of prudence check.

(iii) Developing disaggregated benchmarks of capital cost of individual packages. The summation of relevant packages/elements of a project should add to total hard cost of the project. The financing cost, interest during construction, taxes and duties, right of way charges, cost of R&R etc. would be additional and not to be factored in benchmark costs.

(iv) Developing a model for benchmarking which should be self-validating i.e. as data of new projects gets added to the data base, the benchmark should get revised automatically

3.2 Scope of Assignment

- Step-1: Creation of a database of capital cost of projects; for which data is reliably available.

- Step-2:Analyzing Project Database so created to define Disaggregated Packages of Hard Cost of a Project to be sufficient for benchmarking

- Step-3: Identifying escalation factors and developing financial/pricing models to assign weightages to various such factors, test accuracy with historical data from project database and developing escalation formula for each disaggregated benchmark with due weightage to various materials.

Hard cost for Transmission Lines

- Developing benchmarks for 400 KV and 765/800 KV lines.

- Benchmarking to be developed in terms of rupees per circuit-km for various voltage levels and conductor sizes and 400/765/800 KV transmission line configurations.

- Factoring types of terrains into benchmarks and developing suitable factor for taking into account use of suspension and tension towers, special insulators for heavily polluted areas, tower extensions, large towers for river crossing, various types of tower foundations etc.

- Factoring cost of erection, testing and commissioning and other incidental expenses including site preparation and supervision etc into various disaggregated capital cost heads.

3.3 Deliverables

3.3.1 Stage I Assignment

- Concept Papers on disaggregated bench marks for capital cost for 400 kV AC and 765/800 kV AC transmission lines of different conductor sizes passing through different terrains.

- The concept papers should give clear picture of how the benchmarks would be developed and how much data shall be collected and collated and what would be the degree of reliability and accuracy of the benchmarks.

- Develop/revise draft formats for project costs in view of the proposed disaggregated benchmarks in which future capital costs of projects are to be submitted by the project proponents.

4.0 THE CONCEPT PAPER

The Concept Paper was submitted by the Consortium in November, 2008. The salient features in regard to the concept and the methodology as contained in the paper are summarized below:

4.1 Concept

4.1.1 The word benchmark comes from the field of surveying. The *Oxford English Dictionary* defines a benchmark as

A surveyors mark, cut in some durable material, as a rock, wall, gate pillar, face of a building, etc. to indicate the starting, closing, ending or any suitable intermediate point in a line of levels for the determination of altitudes over the face of a country.

4.1.2 The term has subsequently been used more generally to indicate something that embodies a performance standard and can be used as a point of comparison in performance appraisals. Benchmarks are often developed using data on the operations of agents that are involved in the activity under study. Statistical methods are useful in both the calculation of benchmarks and the comparison process

4.1.3 Statistical benchmarking has in recent years become an accepted tool in the assessment of utility performance. Benchmarking also plays a role in utility regulation in several jurisdictions around the world.

4.1.4 Benchmarking of the performance of utilities is facilitated by the extensive data that they report to regulators.

4.1.5 Worldwide benchmarking is undertaken by the utilities/regulators for improving efficiency and cost control.

4.1.6 The accuracy of estimates of costs is a function of details provided in Detailed Project Report (DPR) or Feasibility Report (FR) with regard to specification of plant, equipment and civil construction. These estimates are generally based on earlier procurement of similar equipment and budgetary prices given by manufacturer. Estimates based on earlier procurements would again depend upon:

- The packaging for the procurement
- Equipment specifications
- The competitiveness in procurement
- Taxes, Tariffs and Trade Policy
- Foreign Market and Currency Fluctuations
- Inflation and Capital Costs.

Thus, within the cost estimates of the project, there is a tendency to build in additional risk factors

4.1.7 Recognized risks in the project configuration relate to such aspects where project designer based his design on certain predictions of assumption which are likely to change due to uncontrollable or force majeure conditions. There are wide ranging factors which create such risks for the developer. These include variations in soil characteristics affecting foundation designs etc. These uncertainties vary in degree and size for each specific project. Mitigation of these uncertainties by more thorough investigation, analysis and planning could bring down the risks/capital costs and operating costs of projects. To the extent it is not possible to eliminate these risk factors, pricing mechanism need to be developed to pass the costs to consumers only when suppliers incur liabilities due to one or more of such risks.

4.2 Methodology

4.2.1 Sources and Basis of Database

- Transmission Lines of the Transmission Utilities of Central/State Sectors and the IPPs completed and/or under implementation with procurement process having been completed are identified sources for collection of data.

- Indigenous / imported equipments and materials for the projects on the basis of the orders placed and records maintained are considered as sources for data collection.

- Procurement process and maintenance of records of the above utilities are according to the applicable rules, regulations, orders and these are considered sources of reliably available data.

- Projects which had been completed or were under completion during the financial years 2004-05, 2005-06, 2006-07, 2007-08 and 2008-09 have been considered for data collection and creation of data base. 1st January, 2009 is considered as the date for normalization of costs through price variation process.

4.2.2 Data Collection Process

- Selection of Transmission Lines from identified list of projects.
- Finalization of Data Collection Formats and Procedure.
- Issue of communication by CERC to the identified utilities for providing assistance and cooperation in data collection and interaction.
- Visit to identified utilities/transmission lines.
- Preliminary discussions with the officials in the power utilities and collection of completed Data Collection Formats.
- Examination of the completed data forms of the utilities, verification and validation based on the records and documents to the extent available.
- Seeking clarifications/explanations and confirmation wherever considered necessary.
- Ascertaining break-up of hard cost of the indigenous and imported equipment and materials procured for the project awarded on EPC contract basis.

4.2.3 Creation of Database

- Project Data Sheet (PDS) for each transmission project.
- PDS of each project contains details of the project made out from the data collection sheets which forms basis for database.

4.2.4 Defining Disaggregated Packages

- Preparation of package-wise equipment and material procured including the cost of each package
- Preparation of cost of services such as erection, commissioning, testing etc. of each package-wise equipment for each project.
- Factoring of cost of services into the cost of respective package.
- Identifying common packages among the projects and preparation of complete list of such packages including their cost.
- Identifying uncommon packages among the projects and preparation of complete list of such packages including their cost.

- Grouping of uncommon packages into the common packages as practicable on the basis of the best technical consideration and procurement practices in order to minimize the uncommon packages.
- Preparation of list of residual packages including their costs.
- Identification of escalation factors and indices considered in respect of each disaggregated package including the formulae used by the utilities for working out the price adjustment.

4.2.5 Developing Benchmarks

- Database of capital cost of project is analyzed and disaggregated packages are defined following the method mentioned above.
- Disaggregated packages so defined are considered as to sufficiency of information for benchmarking.
- Capital cost of each disaggregated package is worked out and given against each package.
- Accuracy test of identified escalation factors is carried out with historical data from the developed project data base and other available sources.
- Financial/pricing model is developed to assign weightages to various escalation factors through recognized indices and cost escalation formula for each disaggregated package.
- Capital cost of each disaggregated package is linked to each financial/pricing model.
- Price variation adjustment occurring on any given date during the validity period of the capital cost of each disaggregated package is in relation to a reference period say, annually.
- Such price adjustment to the capital cost of each disaggregated package is applied uniformly during that period.
- Price adjustment amount arrived at according to the pricing model/cost escalation formula for each disaggregated package is added to the capital cost of the respective disaggregated package.
- Capital cost and the price adjustment amount added to that cost is the benchmarked capital cost of each disaggregated package up to date designated as normalization date.
- This cost is updated on annual basis using the relevant cost escalation factors and formula.
- Summation of relevant package/element of a project is the total hard cost of the project.

4.2.6 Degree of Reliability and Accuracy of Benchmarking

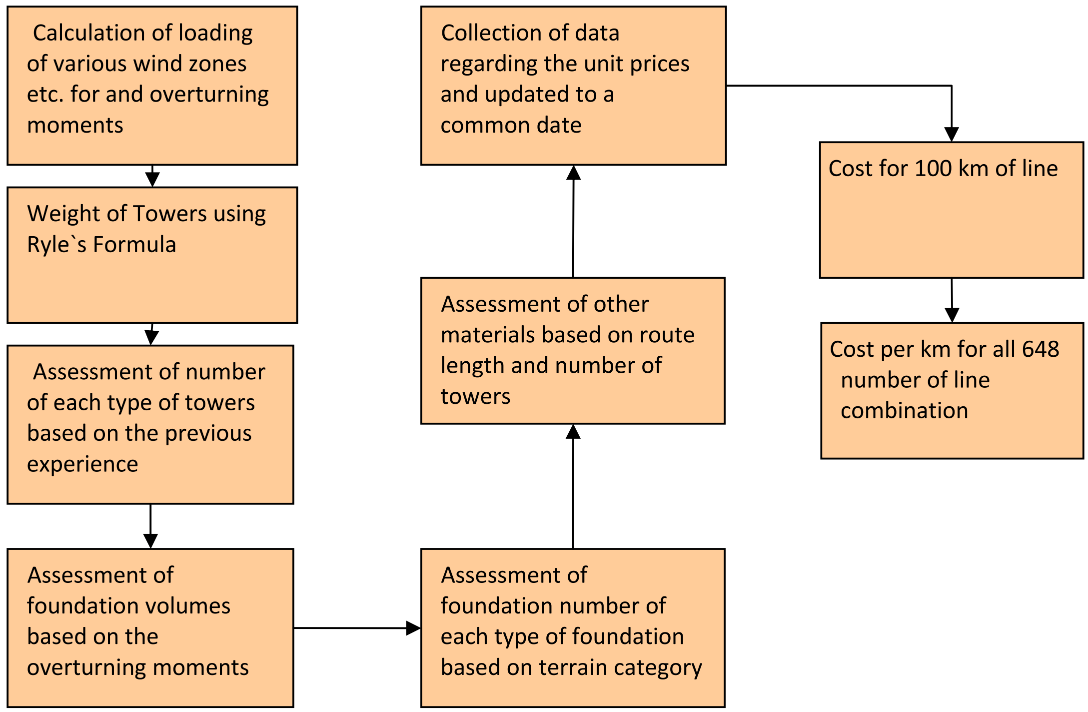
- Each power utility adopts packages for procurement of equipment based on prevailing conditions and considers the package and procedure most suited for the power project.
- Degree of reliability and accuracy of benchmarks rests on data relied upon and stage-wise methodology followed.
- Data relied upon is from the sources of Central, State power utilities and IPPs.
- Data, documents, records and registers available with the above utilities are maintained as per applicable laws, rules, regulations, accounting standards and are subject to audit as per those laws, rules and regulations.
- The benchmarks developed based on such available data are considered to have acceptable reliability and accuracy.

5.1 Main Features considered for Model Creation :

Flow Diagram for Benchmarking the Cost of Transmission Lines

- Transmission Costs
- Major Components involved in the construction of a Transmission Line
- Variables
- Assessment of Towers, Foundations and other materials and the methodology adopted.
- Transmission lines identified for data collection, methodology adopted and the assumptions
- Framework of Concept Model
- Validations in Transmission Line
- Cost of 765 kV SC Line with Quad Conductor for 112 KM length as per the work awarded for supply and erection with Wind Zone + Terrain Category and Plain Area (Predominantly normal soil).
- Comparison of tower wts in MT in a part of 80 KM 400 kV D/C line with quad ACSR moose conductor.

The process for development of model is shown in schematic below.



- Details of activities involved in the transmission lines.
- Salient features of the transmission lines
- Assessment of quantities and preparation of BOQ
- Method of calculation of weights of towers by assessing the total load on the towers based on the wind zone based on Ryle's formula.
- Method of calculation of weights and volumes of foundation.
- Validation of the result of working with available transmission lines.
- Methodology adopted for calculation of total cost based on the available data.
- Usage of escalation formulae as adopted by CTU.
- Identification of transmission lines for collection of data.

6 DATA COLLECTION PROCESS

6.1 CERC Communication

CERC wrote letter to Transmission Utilities in the country.

6.2 Attachments to CERC Letters

1. Names of the identified projects for data collection
2. Data Collection Procedure
3. Identified source of data
4. Data Collection Formats

6.2.1 Names of Projects

The data was collected from PGCIL as well some states transmission utilities. The names of Transmission Lines for which data was collected and have been considered for the model are tabulated below:

S.No	Name of the Line	Voltage Class	S/C or D/C	Length of the Line (km)
1	Pichore-Gwalior	765 kV	S/C	117.5
2	Bina-Pichore	765 kV	S/C	122.5
3	Sasaram-Fatepur	765 kV	S/C	168
4	Balia-Luknow	765 kV	S/C	158
5	Raigarh-Raipur	400 kV	D/C	214
6	Muvattupuzha-North	400 kV	D/C	77.29
7	Ranchi-1-Sipat	765 kV	S/C	292
8	Gaya-Balia	765 kV	S/C	235
9	Bina- Gwalior	765 kV	S/C	122.5
10	Durgapur- Maithon	400 kV	D/C	73
11	Kanpur-Ballabhgrh	400 kV	D/C	132
12	Vapi-Navi Mumbai	400 kV	D/C	185
13	Edamon-Muvattupuzha (Part-I)	400 kV	D/C	73.64
14	Kaithal-Meerut	400 kV	D/C	160
15	Ranchi-Rourkela	400 kV	D/C	143
16	Maithon RB TPS -Ranchi	400 kV	D/C	200
17	Mejia 'B' TPS-Maithon(PG)	400 kV	D/C	57
18	Rourkela-Raigrah	400 kV	D/C	210
19	Sasaram-Biharsharif	400 kV	D/C	195
20	Ranchi(old)-Ranchi(new)(Line-1)	400 kV	D/C	72
21	Ranchi(old)-Ranchi (new) (Line-2)	400 kV	D/C	72
22	Maithon RB TPS- Maithon (PG)	400 kV	D/C	30
23	Maithon -Jamshedpur(LILO at Mejia 'B' TPS)	400 kV	D/C	50
24	Edamon- Muvattupuzha (Part II)	400 kV	D/C	8
25	Bokaro TPS-Kodarma TPS	400 kV	D/C	110
26	Kodarma-Gaya	400 kV	D/C	80
27	Pindwara-Kankroli	400 kV	D/C	114
28	Madurai-Trivandrum	400 kV	D/C	106
29	Bareili-Moradabad and other	400 kV	D/C	165

S.N o	Name of the Line	Voltage Class	S/C or D/C	Length of the Line (km)
	lines			
30	Agra-Jaipur (Package-A2)	400 kV	D/C	110
31	Malerkotla-Jallandhar etc.	400 kV	S/C	118
32	Jodhpur-Merta	400 kV	S/C	110
33	PPSP-Durgapur	400 kV	D/C	185
34	Thamnar-Raipur(Kumhari)	400 kV	D/C	204
35	Nandikur-Hassan	400 kV	D/C	179
36	BTPS-Hiriyur	400 kV	D/C	151
37	Bhoopalapally TPP to Warangal	400 kV	D/C	44

6.2.2 Data Collection Procedure

- The projects/units which have been commissioned and the projects/units in respect of which award of contracts for supply of equipment and services for the projects has been completed and/or under construction/completion during the Financial Years (FY) 2004-005, 2005-06, 2006-07, 2007-08 and 2008-09 were considered for the purpose of data collection, creation of data base and validation of model. Model was also validated with data of lines commissioned prior to 2003.

- Data collection undertaken under the various heads as contained in the Data Collection Formats designed.

- Data collected based on the completed hard cost of the projects/units where the projects/units have been commissioned and the projects/units in respect of which contracts of supply and services had been awarded and are under construction/completion during the above financial years, the data based on the contracts awarded.

- Data on completed projects/units sourced from relevant procurement orders, work orders, contract documents etc. or from other source from the records maintained by the Power Utility which, in the opinion of the Utility, is the reliably available data which could be used for the purpose of the present assignment.

6.2.3 Identified sources of data

S.No.	Source of Data
1	Procurement Orders
2	Work Orders
3	Contract Agreements
4	Others

6.2.4 Data Collection Formats

Transmission Elements General Data (TEGD)

Element-wise break-up of project cost for Transmission System (EBTS)

Variable Factors with impact on Capital Cost.

6.3 Actual Data Collection Status (used for model development)

Utilities	No. of Lines/Projects
Central	30
State	7
Total	**37**

Validation of Transmission Line Model with data of lines not in data base

Name of the Line	Length of Line	Cost as per LoA	Cost as per Model	Difference in Lakhs	% Difference
Agra-Jaipur Line	217.427	13,205.15	13,887.78	682.63	5.17%
Line of 400 KV SC Lucknow-Moradabad line to Bareili	21.733	1791.27	1870.08	78.81	4.40%

7 TRANSMISSION LINE MODEL as developed

7.1 Structure

7.1.1 Major components of Transmission Line

a) Towers & Tower accessories,
b) Tower foundations
c) ACSR Conductor and conductor accessories
d) Ground wire & Ground wire accessories.
e) Insulator & insulator hard ware.

f) Towers and foundations: The weight of towers and volume of foundations varies with the load appearing on the towers and this depends on the wind zone, voltage class, type of conductor etc.
g) Following are the variable factors which influence the weights.
   i. Six Wind zones
   ii. Three Terrain categories
   iii. Two types of conductors, Moose & Bersimis
   iv. Three different types of bundle in the conductor (Twin, Triple and Quad)
   v. Two types of circuits (Single and Double)
   vi. kV class of the line (400 kV and 765 kV)
h) The quantities of other materials depend on the length of the line and no. of towers used in the particular terrain.

7.1.2 Bill of Quantities

The Bill of Quantities of each of the materials is assessed in the following pattern and methodology.

a) Computing Tower weights:
   i. The conductor tension and GW tensions are calculated using sag-tension equations for all terrain categories.
   ii. The loading on towers such as wind load, deviation load, vertical load etc. at various points are calculated for all wind zones, terrain categories and conductor combinations.
   iii. The overturning moments are calculated by using the above loading calculations for all categories of towers using standard configuration of towers.
      - Wind pressures at points of Conductor, GW, Insulators and tower body based on gust response factor, height etc.
      - The sag-tension for different wind conditions and pressures by using the formula $f_2^2 \times \{f_2 -(K-\alpha tE)\} = (l^2\delta^2q_2^2E)/24$. A small programme has been developed for this calculation.
      - Computing the following loadings on towers:
         - ➢ Wind on Conductor
         - ➢ Wind on Insulator
         - ➢ Transverse load of conductor due to deviation.
         - ➢ Wind on ground wire
         - ➢ Transverse load of ground wire due to deviation

iv. The tower weights are calculated using the Ryle's formula $W=k\,H\,\sqrt{M}$

- In order to simplify the methodology for assessing tower weights for cost estimate purposes the following formula devised by Mr. Ryle has been used

$W = k\,H\,\sqrt{M}$

W = Weight of tower in kG.
H = Height of tower in Meters for which the prevailing standard configuration of towers has been used.
M = Total overturning moments at the ground level under normal conditions.
K = constant which depends on the configuration of tower.

- The value of 'k' depends upon the configuration of towers and the same has been calculated based on the available designs.

v. The weights have been assessed for following 1296 numbers of various categories of towers

- 400 kV, DC with twin ACSR Moose conductor:72 Nos
- 400 kV, DC with triple ACSR Moose conductor: 72 Nos
- 400 kV, DC with quad ACSR Moose conductor: 72 Nos
- 400 kV, SC with twin ACSR Moose conductor: 72 Nos
- 400 kV, SC with triple ACSR Moose conductor: 72 Nos
- 400 kV, SC with quad ACSR Moose conductor: 72 Nos
- 765 kV, SC with twin ACSR Moose conductor: 72 Nos
- 765 kV, SC with triple ACSR Moose conductor: 72 Nos
- 765 kV, SC with quad ACSR Moose conductor: 72 Nos
- (6 Wind zones x 3 terrain categories x 4 types of towers)
- Total – 648 Nos.

vi. Similar exercise for ACSR Bersimis is also done with another 648 Nos. of tower types.

b) Computation of tower foundation quantities.
The foundation volumes also depend upon the total foundation loads acting on the foundations. The foundation volumes and weight of reinforcement required for each type of soil have been assessed after

arriving at the overturning moments and using a constant for each type of soil and tower.

c) Computation of other materials:

i. ACSR conductor, Ground wire, Number of towers, insulators and other components are assessed accurately.

ii. The designs & weights of towers and foundations depend on the following:

- Wind zone - 6 Zones
- Terrain category – 3 categories
- Conductor type and No. in the bundle:

7.1.3 Combinations of lines considered in each wind zone and terrain

S.N.	Particulars
	ACSR MOOSE CONDUCTOR
1	400 kV, DC with Twin ACSR Moose Conductor
2	400 kV, DC with Triple ACSR Moose Conductor
3	400 kV, DC with Quad ACSR Moose Conductor
4	400 kV, SC with Twin ACSR Moose Conductor
5	400 kV, SC with Triple ACSR Moose Conductor
6	400 kV, SC with Quad ACSR Moose Conductor
7	765 kV, SC with Twin ACSR Moose Conductor
8	765 kV, SC with Triple ACSR Moose Conductor
9	765 kV, SC with Quad ACSR Moose Conductor
	ACSR BERSIMIS CONDUCTOR
1	400 kV, DC with Twin ACSR Moose Conductor
2	400 kV, DC with Triple ACSR Moose Conductor
3	400 kV, DC with Quad ACSR Moose Conductor
4	400 kV, SC with Twin ACSR Moose Conductor
5	400 kV, SC with Triple ACSR Moose Conductor
6	400 kV, SC with Quad ACSR Moose Conductor
7	765 kV, SC with Twin ACSR Moose Conductor
8	765 kV, SC with Triple ACSR Moose Conductor
9	765 kV, SC with Quad ACSR Moose Conductor

7.2 Essential Features

a) The essential features of the Model are as follows:

i. The length of line
ii. Type of wind zone and terrain category as this decides the tower loading and the weight of tower and foundations
iii. Type of conductor and no. in the bundle. This also is a main factor which decides the total length of conductor, weight of towers, foundations.
iv. Type of land (hilly or plain area) which decides the no. of towers and type of foundations and this in turn decides the total hardware and insulators required.
v. No. of towers of different types

b) These are incorporated in the model and form as input to the model.

c) The Model is able to exhibit / derive the cost for all the 324 types of lines, two different types of land profiles (hilly or plain) and three different types of insulators i.e. Standard porcelain, anti-fog and polymer insulators.

d) PGCIL is now designing towers for 85ºC conductor temperature. This results in increase in the tower height due to increased sag and tower weight. Hence the model has also been prepared for 85ºC in addition to 75ºC.

e) Output of the Model: The Model essentially furnishes the following values:
i. Per km cost of the line
ii. Total cost of the line.
iii. Detailed estimate for all combinations of lines if required

7.3 Main Variables

a) The Main variables of the Model can be listed as follows:
i. The length of the line
ii. No. of 'A', 'B', 'C, and 'D' type towers
iii. No. of River crossing pile foundations
iv. Voltage class of the line (765 kV and 400 kV)
v. No. of Circuits (SC or DC)
vi. Type of Insulators
vii. No. of conductors in the bundle (Twin, Triple or Quad)
viii. Wind zone (zone nos. 1 to 6)
ix. Terrain category

x. Base date

b) These form as the inputs to the Model. In addition, the prevailing taxes and duties are other variable.

7.4 Data Inputs

Data of 37 transmission lines have been obtained from PGCIL and other utilities. They have been collected for different voltage classes, different terrains and different combination of conductors etc. The data inputs of each of the materials of these transmission lines have been tabulated and rates of each of these materials have been updated to a common base as on September-09. The average prices of these materials have been worked out after segregating the taxes and duties for bought out items. These average prices have been considered as the input to the model to arrive at the hard cost of the transmission line. However the Model has a provision to update the rates to any base date as desired. The Model gets updated automatically to that base date.

7.5 Assumptions

Following are some of the assumptions used in the Model.

a) No. of Towers:
The No. of different types of towers are one of the inputs to the Model. However in the absence of the details an approximate quantity of towers which could be used is as follows:

S.N.	Particulars	Normal, Plain terrain	Hilly Terrain
1	'A' type towers	210	70
2	'B' type towers	25	90
3	'C' type towers	25	45
4	'D' type towers	20	80

b) Weights of towers:
"**Ryles**" formula as follows have been used for assessing the weights of towers. In the absence of detailed designs.

i. $W = k\ H \sqrt{M}$
Where

W =Weight of tower in kg.
H =Height of tower in Meters

ii. This requires assessment of total load acting on the tower for each combination and calculation of over turning moments.
iii. The value of 'k' is a constant and has been assessed based on the available designs for each type of configuration of towers.

c) No. and volume of foundations:
Different types of soil such as Normal Dry, Fissured rock, submerged, Black cotton soil etc. are encountered during the execution of transmission lines. The No. of different types of foundations assumed are based on the past experience in different types of terrains.

The volume Concrete required and weight of reinforcement depend on the foundation loads acting on the towers. This again depends on the overturning moments. The foundation volumes and weights are assessed with these details.

7.6 Validation

a) Details of 33 Nos. of transmission lines have been computed and updated to a common base as on September-09.
b) The wind zone and terrain category for each of the lines has been identified.
c) All the necessary data has been fed into the Model.
d) The total cost obtained from the Model has been tabulated and compared with the actual cost.
e) The results are tabulated and furnished below.

Validation results of 33 lines are tabulated as follows:

S.N	Name of the Line	Voltage class	DC or SC	Type of Conductor	No. of Conductor in the bundle	Wind Zone	Route length	Base date of Indices	Actual percentage difference
1	Pichore-Gwalior	765 kV	SC	Bersimis	Quad	4	117.50	Jan/07	**0.61**
2	Bina-Pichore	765 kV	SC	Bersimis	Quad	4	122.50	Jan/07	**-4.69**
3	Sasaram-Fatepur	765 kV	SC	Bersimis	Quad	4	168.00	Mar/08	**6.20**
4	Balia-Luknow	765 kV	SC	Bersimis	Quad	4	158.00	Dec/07	**-2.65**
5	Raigarh-Raipur	400 kV	DC	Moose	Twin	2	214.00	Jan/07	**0.14**
6	Muvattupuzha-	400 kV	DC	Moose	Quad	2	77.29	Nov/07	**-4.23**

S.N	Name of the Line	Voltage class	DC or SC	Type of Conductor	No. of Conductor in the bundle	Wind Zone	Route length	Base date of Indices	Actual percentage difference
	North								
7	Gaya-Balia	765kV	S/C	Bersimis	Quad	2	235.00	Dec/07	3.09
8	Bina-Gwalior	765kV	S/C	Bersimis	Quad	2	122.50	Aug/07	5.25
9	Durgapur-Maithon	400kV	D/C	Moose	Twin	4	73.00	Jun/07	5.85
10	Vapi-Navi Mumbai	400kV	D/C	Moose	Twin	2	185.00	Jun/07	-8.30
11	Edamon-Muvattupuzha (Part-I)	400kV	D/C	Moose	Quad	2	73.64	Nov/07	2.71
12	Ranchi-Rourkela	400kV	D/C	Moose	Twin	2	143.00	Jan/07	-1.63
13	Maithon RB TPS - Ranchi	400kV	D/C	Moose	Twin	2	200.00	Feb/07	-5.77
14	Mejia 'B' TPS-Maithon(PG)	400kV	D/C	Moose	Twin	2	57.00	Feb/08	3.13
15	Rourkela-Raigrah	400kV	D/C	Moose	Twin	2	210.00	Jan/07	-2.34
16	Sasaram-Biharsharif	400kV	D/C	Moose	Quad	4	195.00	Feb/09	3.76
17	Maithon RB TPS-Maithon (PG)	400kV	D/C	Moose	Twin	4	30.00	Feb/08	1.45
18	Edamon-Muvattupuzha (Part II)	400kV	D/C	Moose	Quad	2	75.18	Nov/07	3.35
19	Bokaro TPS-Kodarma TPS	400kV	D/C	Moose	Twin	2	110.00	Mar/08	-9.37
20	Kodarma-Gaya	400kV	D/C	Moose	Quad	2	80.00	Mar/08	0.68
21	Pindwara-Kankroli	400kV	D/C	Moose	Twin	4	114.00	Oct/06	3.03
22	Madhurai-Trivandrum	400kV	D/C	Moose	Twin	2	106.00	Mar/05	5.92
23	Bareili-Muradabad	400kV	D/C	Moose	Twin	4	165.00	Mar/04	-9.24
24	Agra-Jaipur	400kV	D/C	Moose	Twin	4	110.00	Jan/04	0.49
25	Malerkotla-Jallandar	400kV	S/C	Moose	Twin	4	118.00	Jul/04	-0.22
26	Sipat-Raipur	400kV	D/C	Moose	Twin	2	148.00	May/05	3.97
27	Lakhisarai-Patna	400kV	D/C	Moose	Quad	4	124.00	Dec/03	6.17
28	Khandwa-Raigarh	400kV	D/C	Moose	Twin	2	102.00	Sep/04	5.29
29	Jodhpur-Mertha	400kV	S/C	Moose	Twin	4	110.00	Feb/08	-2.79
30	PPSP-Durgapur	400kV	D/C	Moose	Twin	4	185.00	Feb/08	-4.11
31	Mangalore-Hassan	400kV	D/C	Moose	Quad	2	179.00	Sep/08	-0.43
32	BTPS-Hiriyur	400kV	D/C	Moose	Twin	1	151.00	Feb/08	-2.63
33	Bhoopalapally TPP to Warangal	400kV	D/C	Moose	Twin	3	44.00	Nov/08	-5.14

8 PRICE VARIATION MODELS

8.1 Essential Features

The price variation for the following components of Transmission lines are considered:

a) Steel Structures
b) Conductors
c) Ground wire
d) Insulators
e) Hard ware fittings
f) Conductor & ground wire accessories
g) Steel reinforcement & Foundations
h) Erection works

8.2 Indices

The price indices of various materials are governed by the indices published in the monthly IEEMA Journals.

The price indices of following raw material are used for transmission lines:

S. N.	Basic Raw material	
1	Structural Steel Heavy Angles	S1/So
2	Electrolytic High Grade Zinc	Zn1/Zno
3	Labour-Consumer Price Index	L1/Lo
4	High Tensile Galv. Steel Wire	W1/Wo
5	Wholesale Prices of Fuel etc.(Base 93-94=100)	F1/Fo
6	EC Grade Al Ingots	Al1/Alo
7	Wholesale prices of Iron and Steel	I1/Io
8	Whole Sale Price Index : (HSD)	D1/Do
9	Cement	C1/Co
10	Non Metallic mineral products	M1/Mo
11	Index No. of Insulators (Base 2003= 100)	In1/Ino

8.3 Price Variation Formulae

Materials	Formulae used in model in line with CTU formulae
Towers	P1=Po[0.15+0.66(S1/So)+(0.08x(Zn1/Zno)+0.11(L1/Lo))-Po
ACSR	P1=Po[0.15+0.65(Al1/Alo)+0.15x(W1/Wo)+0.05x(L1/Lo)]-Po

Materials	Formulae used in model in line with CTU formulae
Ground Wire	P1=Po[0.15+0.74(W1/Wo)+0.11x(L1/Lo)]-Po
Insulator	P1=Po[0.15+0.05(Zn1/Zno)+0.53x(F1/Fo)+0.27x(L1/Lo)]-Po
H/W Fittings	P1=Po[0.15+0.43(Al1/Alo)+0.05x(Zn1/Znoo)+0.21x(I1/Io)+0.16x(L1/Lo)]-Po
Conductor & GW Accessories	P1=Po[0.15+0.70(Al1/Alo)+0.15x(L1/Lo)]-Po
GW Clamps	P1=Po[0.15+0.65(I1/Io)+0.05x(Zn1/Zno)+0.15x(L1/Lo)]-Po
Tower erection	ER1=ERo[0.20+0.22(D1/Do)+0.58x(L1/Lo]-ERo
Steel Reinforcement	dER=ERo[0.20+0.10x(D1/Do)+ 0.05x(L1/Lo)+0.65x(I1/Io]-ERo
Concreting	dER=ERo[0.20+0.20x(D1/Do)+ 0.10x(L1/Lo)+0.30x(C1/Co)+0.2X(M1/Mo)]-ERo

8.4 Validation

The PV formulae used in the model are based on the formulae followed by CTU. These formulae are slightly different than that of IEEMA but are reasonable, rationally designed for 400/765/800 Kv lines the subject matter of study.

9 ACCURACY AND CONFIDENCE LEVELS OF MODEL

9.1 The models that have been developed based on the data available, as also, reworked data indicate that at the System Capital Cost level, the accuracy level works out to a maximum of ± 5% range.

9.2 Confidence level of up to 98% can be expected from the results of these models.

10 DEVELOPING/REVISION OF DRAFT FORMATS OF PROJECT COSTS

10.1 The existing Forms contained in Appendix I of the CERC (Terms and Conditions of Tariff) Regulations, 2009 have been reviewed and revised. The revised forms will be incorporated at the time of notification of benchmark cost.