Enhancing Competitive Advantage in Hydro Power Station by adopting Risk Management Process in Renovation, Modernization, Upgradation and Life Extension Projects in India

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Abstract - Hydro Power is one of the benign sources of energy. Considering the benefits associated with the Hydro Power Projects, continuous operation and sustenance of the existing hydro power plants in India is the requirement of the hour. This will not only lead to infuse new life to the existing Hydro Power Projects but also help in sustainable development of the energy sector. As per the CERC the normative operative economic life of any hydro power station is 35 years and till 1985 the total installed capacity of hydro power projects in India was 14460 MW (data from CEA). Some of the utilities in India such as UJVNL, OHPC, KSEB, BBMB, TNEB etc. have started infusing new lease of life to its existing old hydro power station through Renovation, Modernization & Upgradation (RMU) program, which is still in its nascent stage. But only few hundred MW of the existing capacity, i.e. out of 14460 MW, has been touched so far. Also as the year goes off this 14660 MW capacity goes on increasing and more Hydro Power Projects in India will be lined up for consideration under RMU program. RMU projects are very complex in nature as construction and operation goes simultaneously at the same Project. Risks associated at different stages of such Projects are very different in reference to Green Field Projects. Not much work has been done on the risks associated with RMU of Hydro Power Stations. This research work will try to identify different kind of risk associated at different stages of RMU Projects. After identification of Risks, severity of those risks will be assessed and finally a framework for Risk Management in RMU of Hydro Power Station will be constructed.

Keywords - Hydropower, Renovation, Modernization & Upgradation, Competitive Advantage, Performance

1. Introduction

Power Sector of India is being governed by Ministry of Power at Central level and State Government has its own department to look into the sector in the State territory. Power Sector is mainly divided into three parts Generation, Transmission & Distribution. Generation of power is being contributed by Central, State & Private sectors.

1.1 Hydropower Sector of India

Indian power sector is undergoing significant change with the programs like '24 X 7- Power for All', DDUGJY, UDAY, IPDS etc. which aims to provide the quality & reliable power to all. But these programs are having major emphasis on the distribution systems. Distribution system of the power sector is backed by the Generation & Transmission, without which these programs will not be able to reap results as per the expectations. In India, Power Generation is majorly categorized by its nature of production i.e. Thermal, Nuclear, Hydro & RES (Renewable Energy Sources. As on 31.12.2016 total installed capacity for power generation in India is 310005.28 MW with Thermal, Nuclear, Hydro & RES contributing 215168.90 MW, 5780.00 MW, 43139.43 MW and 45916.95 MW (including 4323.37 MW of Small Hydro Project) respectively. Thus, Hydro Power Generation contributes 13.9 % of overall installed capacity and if a capacity of small hydro projects (part of RES) is also included the figure comes out to be 15.31%.

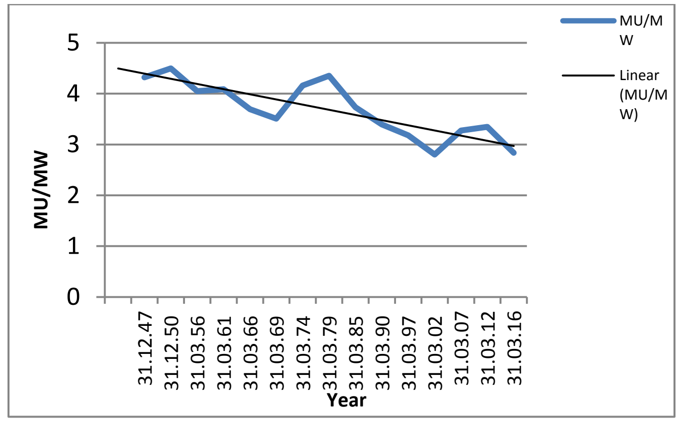
The percentage of Hydro in overall power mix has come down from 37.30% in 1947 to 13.9% in 2016. Hydropower capacity ratio has been continuously decreasing since its peak in 1966 (45.69%). During liberalization in first half of 90's share of hydropower were around 28% which reduced to 25.51% by the end of 8th five year plan (1992-1997) and 25.40% by the end of 9th five year plan. Since then it is continuously decreasing as compare to other and on 31.12.2016, after completion of 11th five year plan and running 12th five year plan the hydro power installed capacity is of the tune of 43,139 MW against the total installed capacity of 310005 MW, which is only 13.92% (Table 1 : Source CEA).

1.2 Performance of Hydro Power Sector

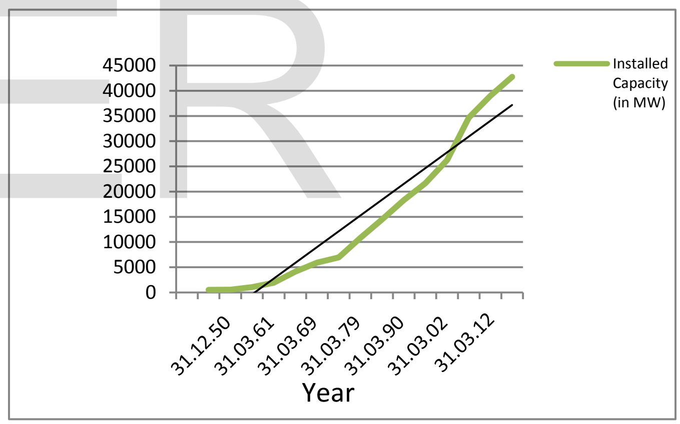
In spite of total 1, 48,701 MW (Source CEA) hydropower potential in India, above table clearly indicates that the hydro power sector is not developing at the pace in comparison to Thermal & RES. In comparison to available hydropower potential only 43139 MW i.e. 29% have been tapped till date. In addition to above hydro power potential 4323 MW of small hydro power have also been developed. Even after including the capacity of small hydro projects the total installed capacity of hydropower in India is around 15.31 %, which is way below the required power mix of thermal : hydro :: 60:40[1]. In last six months i.e. from 30.06.2016 to 31.12.2016 this ratio has declined about 0.2%. The above disparity in the development of the hydro power sector viz-a-viz Thermal & RES is due to various associated barriers. Moreover, instead of continuous little addition of hydropower project in power mix, per MW generation from hydro is not increasing. Table below shows the performance of the hydro projects per MW:

Sl. No.	Year	Installed Capacity (in MW)	Generation (in MU)	MU/MW
1	31.12.47	508	2195	4.32
2	31.12.50	560	2519	4.50
3	31.03.56	1061	4295	4.05
4	31.03.61	1917	7837	4.09
5	31.03.66	4124	15225	3.69
6	31.03.69	5907	20723	3.51
7	31.03.74	6966	28972	4.16
8	31.03.79	10833	47159	4.35
9	31.03.85	14460	53948	3.73
10	31.03.90	18307	62116	3.39
11	31.03.97	21658	68901	3.18
12	31.03.02	26269	73579	2.80
13	31.03.07	34654	113502	3.28
14	31.03.12	38990	130511	3.35
15	31.03.16	42783	121377	2.84

Table 2: Generation (in Million Units) per MW of installed capacity (MU / MW) (Source: CEA)



Graph 1: Trend of increase in installed capacity of hydro power in India
Graph 2 : Trend of generation per MW in India



1.3 Performance of existing hydropower plants

Above two graphs clearly indicates that in spite of addition of new hydro power stations in India, the per MW generation is decreasing continuously. This diminishing generation from existing hydropower plants of India is due to any of the following reason:

- unviable projects,
- unviable installed capacities,
- over-optimistic hydrological assumptions,
- over development (development beyond the carrying capacity of the basin),
- catchment degradation,
- high rates of sedimentation,
- inadequate Repair & Maintenance,
- changing monsoon patterns due to climate change

[1] A hydro-thermal mix of 60:40 is often considered ideal; but it is not sacrosanct. Nevertheless, a higher component of hydropower is preferred from the system operation point of view

The first four reasons as stated above are not the part of this study as the Detailed Project Report (DPR) of all the large hydropower station are being reviewed and approved by Central Electricity Authority (CEA). Before approving the proposed HEP, CEA do a prudence check on the aspects of the proposed plant, only then it gives the Techno-economic Clearance (TEC) of the project. Last four reasons seems to be justified as the generation from HEP is dependent on the discharge in the river, which is directly affected by rate of sedimentation, catchment degradation and monsoon. Less discharge may be a reason for less generation, but these factors are also not being considered in this study. Thus, the reasons may be categorized as the following and the scope of study is limited to the internal factors at operation stage as the projects are generating lesser and lesser. The extrinsic factors are not being included in this research.

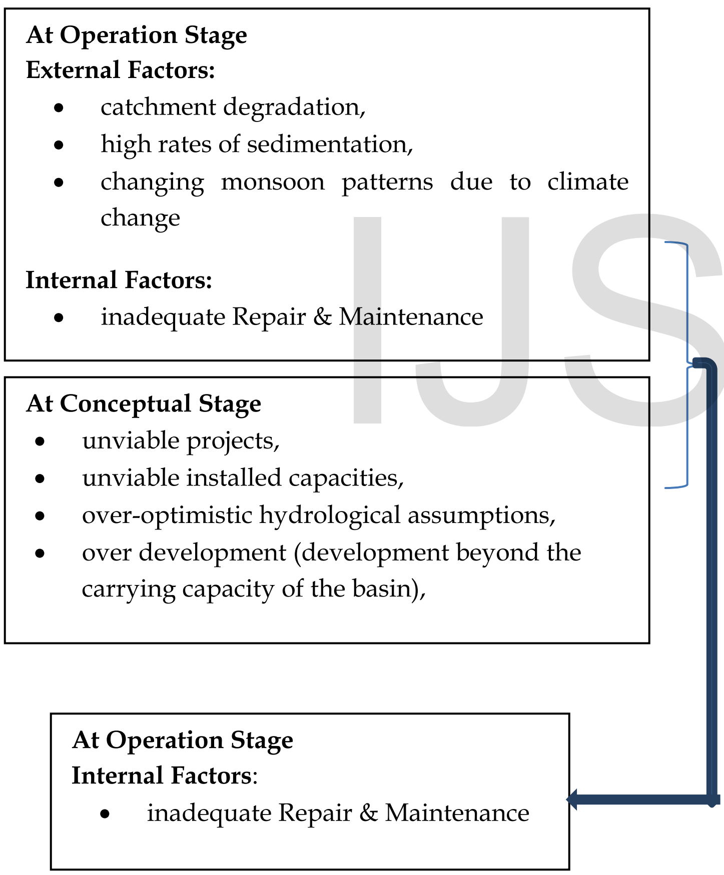


Figure 1: Area of concern

Inadequate repair & maintenance, of hydro power machines and its associated equipment lead to the failure of its components. This failure is also denoted as outage of the unit. These outages shall result in the downtime of the units and hence cause generation loss. There are mainly two types of outages: Planned Outage and Forced Outage.

1.4 Outages

Diminishing generation from the existing hydro power station of India is a grave concern. This research work is more confined towards the management of Operation & Maintenance of hydropower plants which is more intrinsic to the Projects and is controllable; other factors as stated above are not controllable during the operation of the projects. Generation loss from any hydropower station depends on the two following outages:

1. **Planned Outages** : These outages are being planned for regular maintenance of the plants.
2. **Forced Outages** : These outages occurred due to failure of equipment / facilities during operation of the machine / plant.

Planned outages do not contribute to the generation loss as there are planned and are generally carried out during low discharge period in the year. Therefore, planned outage is not the concern for this study; however, forced outages are the fault which occurs when the machine is in operation and result in generation loss. The area of this research is more concerned about these forced outages.

As per last five year performance review done by CEA the forced outages in hydropower sector are as follows:

(Source CEA)

Sl. No.	Year	No. of Machines	Capacity (in MW)	Total Annual Forced Outage (in Hour)	Annual Forced Out age / Machine (in Hour)
1	2	3	4	5	6 = 5 /3
1	2011-12	620	38990.40	310190	500.30
2	2012-13	634	39491.40	145258	229.11
3	2013-14	653	40531.41	290413	444.74
4	2014-15	659	41267.42	222126	337.07
5	2015-16	676	42783.42	235360	348.17

Table 3: Forced outages at existing hydropower station due to breakdown of equipment

From above table the values mentioned at column no. 6 are quite large and are contributing huge generation loss from hydropower station. Average annual forced outage per machine of hydropower is ranging from 229.11 hours (9.5 days) to 500.30 hours (20 days). Annual forced outage of 10 to 20days per year is quite alarming on account of failure of equipment after performing regular maintenance of the plants. The above outages can be minimized by proper

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maintenance of the machines / equipment / facilities at the power stations. Following maintenances are being carried out at the hydro power stations:

1.5 Maintenance of hydropower Plants

Short term maintenance programs:

Short term maintenance is the regular maintenance of the machines. There are two types of this maintenance:

- Annual maintenance: Each machine is being maintained during the lean discharge period. These are short period maintenance of the machines being carried out annually ranging from 25 to 45 days.
- Capital maintenance: These are relatively long duration maintenance (generally 5 to 6 months). These are cyclic in nature and every year one machine is taken under this maintenance.

Long term maintenance program:

- Renovation, Modernization & Upgradation of the Plant: As per CEA normal operative life of any hydro power station is 35 years. After completion of operative life this maintenance (as Project) is normally taken up by the utility.

Effect of aging on annual forced outage of hydro machine is not very clear from table 3.

From Table 4 it is imperative that the older machines / equipment at hydropower stations are more prone to forced outages as compare to the newly installed machines / equipment. The comparison of the annual forced outage per machines (between total number of machines and old machines) are as follows:

Sl. No.	Year	Annual Forced Out age / Machine for all machines (in Hour)	Annual Forced Out age / Machine for old machines (in Hour)	Difference
1	2	4	5	6 =5-4 (% of 4)
1	2011-12	500.30	637.04	137.01 (27.4%)
2	2012-13	229.11	263.47	34.36 (15%)
3	2013-14	444.74	457.79	13.05 (3%)
4	2014-15	337.07	417.80	80.73(23.95%)
5	2015-16	348.17	409.42	61.25 (17.6%)

Table 5: Comparison of annual forced outage of old machines and overall machines

From above table it evident that except for year 2013-14, the forced outages at old power station are more than 15% higher than the overall annual forced outage of that particular year. This clearly indicated that special maintenance, other than regular annul & capital maintenance, of old machines are required to reduce the annual forced outage.

1.6 Financial Loss on account of additional annual forced outages of the old unit

Forces outages of the hydropower machines are contributing in the financial loss to the utilities due to non-availability machines during the availability of discharge.

From Table-6 the total financial loss occurred in last five years by the old hydropower machines, calculated at the MCP rate of IEX (as on 28.01.2017) @ Rs. 2.5per unit of electricity, is Rs. 9428.77 Crore out of which Rs. 1408.16 Crore is additional in comparison to average forced outage if all hydro machines are considered.

The financial losses on account of forced outages of the old hydropower machines, even after performing regular annual & capital maintenance is quite high and alarming. There is an opportunity in this area to save financial loss by under taking comprehensive Renovation, Modernization & Upgradation (RMU) of the old hydropower stations.

1.7 Renovation Modernization & Upgradation of Hydro Power Stations

Renovation Modernization & Upgradation (RMU) of a hydro power station in present scenario of resource constraint is considered to be a best option for bridging the demand supply gap and also to retain the already existing capacities of the old hydro power station. RMU schemes are quicker to complete as compare to new green site projects. Considering the benefits of RMU Government of India had set up a National Committee in 1987 to formulate strategy for R&M of hydro power projects. Based on the recommendations of the National Committee and subsequent reviews, a programme for Renovation, Modernization and Uprating of Hydro Power Stations was formulated by Central Electricity Authority in which 55 schemes were identified with an aggregate capacity of 9653 MW. The total costs of these schemes were estimated as Rs.1493 Crore with expected benefit of 2531 MW. Similar targets have been kept for the forthcoming five year plans.

Following schemes are presently being monitored by CEA:

1. R&M : Renovation & Modernization
2. RM & LE : Renovation, Modernization & Life Extension
3. RMU & LE : Renovation, Modernization, Upgradation & Life Extension

Looking up the cost for these programs at various hydropower station, it can be inferred that the scope of work for each plant is different.

UJVN Limited has taken up RMU & LE of its old power stations and RMU works on three of its Projects have already been completed. The details of forced outages after completion of the RMU & LE Projects at these stations are as follows:

Name of Project	Installed capacity	Annual Forced Outages : 2015-16
Mohammadpur	3 x 3.1 MW	197.07
Pathri	3 x 6.8 MW	243.22
Khatima	3 x 13.4 MW	Completed in Sept 2016 (adequate data not available)

Table 7: Forced outages at Pathri & Mohammadpur after completion of RMU

Table 7 indicates that the annual forced outages in 2015-16 after completion of RMU at Pathri and Mohammadpur are 243.22 hours and 197.07 hours respectively, which 30% and 43.4% lower as compare to national annual forced outage average of 348.17 hours. In addition to the reduction in forced outages, the plant efficiency has also increased. The performance of the plants in comparisons to average generation before RMU & LE can be seen from the table below:

Name of Project	Average Generation Before RMU	Generation after RMU (2015-16)	% Increase
Mohammadpur	40	54	35%
Pathri	100	128	28%

Table 8: Comparison of generation in pre & post RMU & LE of Pathri & Mohammadpur

Thus, RMU & LE is a very profitable avenue not only to reduce the forced outages but also help in increasing the efficiency of the machines and equipment installed in the existing plant.

Benefits of RMU & LE of Hydro Power Plants:

Following benefits are associated with the RMU & LE of hydro power plants:

- No or minimum clearances are required;
- Less gestation period;
- Less risk;
- Less cost against equivalent new project;
- Easy financing;
- Accommodate basin development at later date;
- Technological advancement;
- Use of safety margins and overload margins in the old design;
- Life extension of the existing facilities.

Conclusion

The author is researching on the subject and this will help in creating competitive advantage for the utilities with such knowledge. The competitive advantage should be created, it is not inherited. Porter divides the production factors into the following categories:

1) Human resources;
2) Natural resources;
3) Knowledge resources;
4) Capital resources;
5) Infrastructure.

Increasing knowledge resources is one of the factors will give competitive advantage to a firm against its competitor in the industry. This study will help in achieving economies of scale in information gathering and access to unique resources. By applying this strategy in a volatile and inefficient market, the company has potential to gain competitive advantages over its competitors. This strategy can be very helpful in countries with weak institutional systems since firms with more abilities to exploit unique resources and information will win the market. Timely, implementation of RMU&LE Projects of Hydro power shall provide higher efficiency of the machines

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and hence more quality power, which will be devoid of if proper risk framework is not utilized during implementation of these Projects. Presently, power sector is regulated sector but the essence of Electricity Act 2003 provides for competitive market in long run. Therefore, this research will not only help in present context but help the utilities in long run.

Most commonly used measures for Project Performance are: Time & Cost. Effective implementation of Project is directly related to convert the uncertainties into identified Risks and create a model to overcome such risk during its occurrence. Thus, creating such risk framework for any project help in fast decision making.

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Sl. No.	Year	Thermal (in MW)	Nuclear (in MW)	Hydro (in MW)	RE (in MW)	Total (in MW)	% (of hydro with total)
1	31.12.47	854	0	508	0	1362	37.30%
2	31.12.50	1153	0	560	0	1713	32.69%
3	31.03.56	1825	0	1061	0	2886	36.76%
4	31.03.61	2736	0	1917	0	4653	41.20%

5	31.03.66	4903	0	4124	0	9027	45.69%
6	31.03.69	7050	0	5907	0	12957	45.59%
7	31.03.74	9058	640	6966	0	16664	41.80%
8	31.03.79	15207	640	10833	0	26680	40.60%
9	31.03.85	27030	1095	14460	0	42585	33.96%
10	31.03.90	43764	1565	18307	0	63636	28.77%
11	31.03.97	61010	2225	21658	902	85795	25.24%
12	31.03.02	74429	2720	26269	1628	105046	25.01%
13	31.03.07	86015	3900	34654	7760	132329	26.19%
14	31.03.12	131603	4780	38990	24504	199877	19.51%
15	30.06.16	211640	5780	42848	42849	303117	14.14%
16	31.10.16	212469	5780	43112	45917	307278	14.03%
17	31.12.16	215169	5780	43139	45917	310005	13.92%

Table 1: Capacity addition since independence in different categories (Source CEA)

(Source CEA)

Sl. No.	Year	Year of Commissioning	Number of Machines	Installed Capacity (in MW)	Forced Outage (in Hr)	Non Availability per Machine (in Hr)
1	2011-12	1978-79 to 1988-89	124	7275.60	56232	453.48
		1967-68 to 1977-78	82	5300.25	79992	975.51
		Upto 1966-67	164	4682.05	99480	606.59
		Sub Total	370	17257.9	235704	637.04
2	2012-13	1978-79 to 1988-89	124	7275.60	16079	129.67

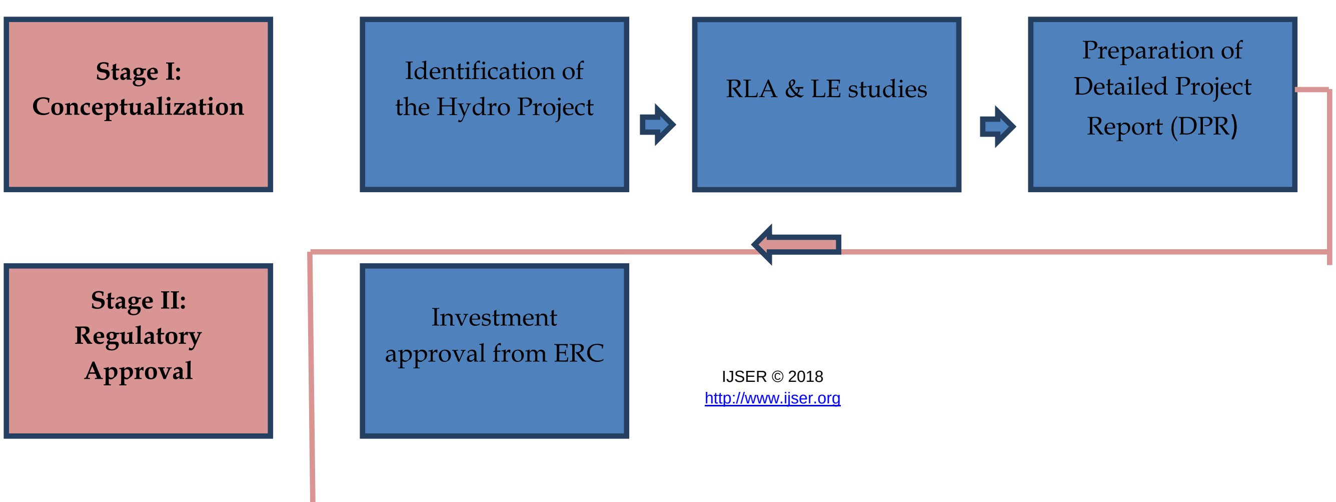
		1967-68 to 1977-78	82	5300.25	16074	196.02
		Upto 1966-67	164	4682.05	65329	398.35
		Sub Total	370	17257.9	97482	263.47
3	2013-14	1978-79 to 1988-89	124	7275.60	26616	214.64
		1967-68 to 1977-78	82	5300.25	38858	473.88
		Upto 1966-67	164	4682.05	103907	633.58
		Sub Total	370	17257.9	169381	457.79
4	2014-15	1978-79 to 1988-89	124	7275.60	38173	307.84
		1967-68 to 1977-78	82	5300.25	21611	263.55
		Upto 1966-67	164	4682.05	94803	578.07
		Sub Total	370	17257.9	154587	417.80
5	2015-16	1978-79 to 1988-89	124	7275.60	41464	334.39
		1967-68 to 1977-78	82	5300.25	26351	321.35
		Upto 1966-67	164	4682.05	83669	510.18
		Sub Total	370	17257.9	151484	409.42

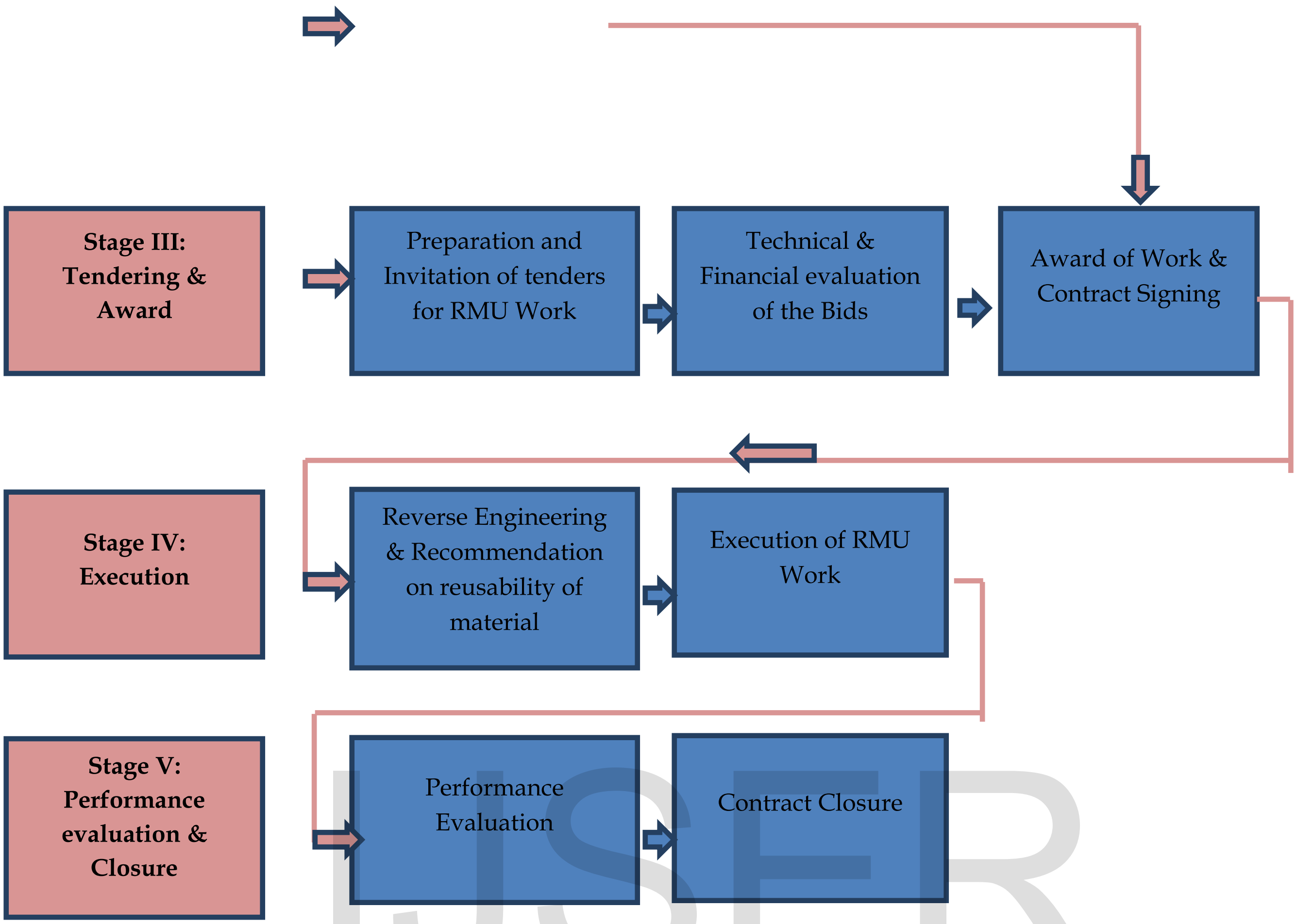
Table 4: Annual forced outage of the machine commissioned till 1988-89

Sl. No	Year	Number of old machine	Capacity (in MW)	MW/ machine	Annual Forced Out age / Machine for all machines (in Hour)	Annual Forced Out age / Machine for old machines (in Hour)	Loss due to forced outages (in MU)	Financial loss due to forced outages (INR Crore)	Difference (in Hour)	Additional loss (in MU)	Financial Loss (INR Crore)
1	2	3	4	5	6	7	8 = 3*5*7/1000	9 = 8*Rs 2.5/10	10 = 7-6	11= 3*5*10/ 1000	12 = 11* Rs.2.5 /10
1	2011-12	370	17258	46.64	500.3	637.04	10993.27	2748.32	137.01	2364.35	591.09
2	2012-13	370	17258	46.64	229.11	263.47	4546.65	1136.66	34.36	592.94	148.24
3	2013-14	370	17258	46.64	444.74	457.79	7899.99	1975	13.05	225.20	56.3
4	2014-15	370	17258	46.64	337.07	417.8	7209.89	1802.47	80.73	1393.14	348.29
5	2015-16	370	17258	46.64	348.17	409.42	7065.28	1766.32	61.25	1056.98	264.24
							37715.08	9428.77		5632.62	1408.16

Table 6: Statement of financial loss due to forced outage of hydropower machines.

Figure 2: Flow diagram of RMU & LE Project:




Stage III:
Tendering &
Award
Preparation and
Invitation of tenders
for RMU Work
Technical &
Financial evaluation
of the Bids
Award of Work &
Contract Signing
Stage IV:
Execution
Reverse Engineering
& Recommendation
on reusability of
material
Execution of RMU
Work
Stage V:
Performance
evaluation &
Closure
Performance
Evaluation
Contract Closure