Chapter II

Performance Audit relating to Power Sector Undertakings

Operational Performance of Major Hydro Electric Projects of Kerala State Electricity Board Limited

Executive Summary

Introduction

Kerala State Electricity Board Limited (KSEBL) was incorporated under the Companies Act, 1956 on 14 January 2011 and started operations as an independent company with effect from 1 November 2013. KSEBL manages the activities of transmission, generation and distribution of power in the State through three strategic business units (SBU), viz. SBU-Transmission, SBU-Generation and SBU-Distribution. The total installed capacity of KSEBL as on 31 March 2019 was 2,237.59 Megawatt (MW), of which 2,058.75 MW (92 per cent) was hydel. The total hydel power capacity was accounted for by 12 major Hydro Electric Projects (HEPs) (1,935 MW) and 23 small HEPs (123.75 MW). The Performance Audit covered the operational performance of three major HEPs of KSEBL, viz. Idukki, Sabarigiri and Kuttiyadi, for a period of five years from 2014-15 to 2018-19. The three major HEPs constituted 65 per cent of the total hydel generation capacity and 63.60 per cent of the total generation capacity of KSEBL.

Non–adherence to hydro generation policy

Failure of KSEBL to adhere to its hydro generation policy and step up the generation of power from the HEPs to meet the additional demand during the peak hours of summer months led to purchase of 86.40 MU of power incurring ₹25.31 crore.

Delay in rectifying defect due to bifurcation of penstock

Bifurcation of penstock of Kuttiyadi HEP for supplying water to the generating stations of Kuttiyadi Extension Scheme led to flow instabilities and consequent reduction of generation capacity by 10 MW. Though the problem was first noticed in 2003, delay in rectifying this led to generation loss of 178.70 MU of power and consequent purchase of power incurring ₹52.36 crore.

Runner erosion due to construction of weir across tail race

The construction of a weir across the tail race channel of Kuttiyadi Additional Extension Scheme led to lack of proper aeration in the runner housing of the generating unit. This forced KSEBL to reduce the generation capacity by 20 MW resulting in generation loss of 133.80 MU of power and consequent purchase of power incurring ₹39.20 crore.

Non-exploration of possibility of uprating

Failure to utilise the uprating potential of first stage units of Idukki HEP and of units 1, 2, 3 and 5 of Sabarigiri HEP resulted in loss of generation capability of 212.04 MU of power per annum, which could have reduced the power procurement by KSEBL to that extent.

Plant Availability Factor

The Plant Availability Factor of the HEPs was affected by considerable amount of forced outages due to improper execution of maintenance works. This resulted in generation loss of 920.71 MU of power and additional expenditure of ₹269.77 crore towards purchase of power.

Renovation, Modernisation and Uprating of Idukki HEP

Defective technical evaluation of the bids delayed the award of Renovation, Modernisation and Uprating (RMU) works of Idukki HEP by 21 months. The RMU works of three units of Idukki HEP was to be completed by July 2019. As of October 2019, the RMU works of only one unit was completed.

Renovation, Modernisation and Uprating of Sabarigiri HEP

Unit 4 of Sabarigiri HEP failed to perform in accordance with the parameters guaranteed by the contractor. The unit was under forced shut down due to technical problems for 1,366:49 hours during the defect liability period and for 5,221:18 hours after the defect liability period causing generation loss of 201.60 MU of power and additional expenditure of ₹59.07 crore towards purchase of power.

Introduction

2.1 Kerala State Electricity Board was a statutory body constituted on 1 April 1957 under Section 5 of the Electricity (Supply) Act, 1948 (Act) for the coordinated development of generation, transmission and distribution of electricity in the State of Kerala. As per the provisions of the Electricity Act 2003, KSEB continued as a State Transmission Utility and Distribution Licensee performing the same functions till 31 October 2013. Kerala State Electricity Board Limited (KSEBL) was incorporated under the Companies Act, 1956 on 14 January 2011 and started operations as an independent company with effect from 1 November 2013. KSEBL manages the activities of transmission, generation and distribution of power in the State through three strategic business units (SBU), *viz*. SBU-Transmission, SBU-Generation and SBU-Distribution.

The electricity demand of the State is met through generation from KSEBL and purchase from Central Generating Stations, Independent Power Producers, power exchange and traders. At present, the power generation of KSEBL comprises a mix of hydel, thermal, solar and wind power stations. The total installed capacity of

KSEBL as on 31 March 2019 was 2,237.59 Megawatt[17] (MW), of which 2,058.75 MW (92 *per cent*) was hydel, 159.96 MW (7.15 *per cent*) thermal, 16.85 MW (0.75 *per cent*) solar and 2.03 MW (0.09 *per cent*) wind. The total hydel power capacity of 2,058.75 MW was accounted for by 12[18] major Hydro Electric Projects (HEPs)[19] (1,935 MW) and 23 small HEPs[20] (123.75 MW). Out of 35 HEPs, Idukki HEP has the highest capacity (780 MW), followed by Sabarigiri HEP (340 MW) and Kuttiyadi HEP (225 MW).

Audit scope and sample

2.2 The Performance Audit covered the operational performance of three major HEPs of KSEBL, *viz*. Idukki, Sabarigiri and Kuttiyadi, for a period of five years from 2014-15 to 2018-19. The three major HEPs constituted 65 *per cent* of the total hydel generation capacity and 63.60 *per cent* of the total generation capacity of KSEBL.

Audit objectives

2.3 The objectives of the Performance Audit were to assess whether:

- the HEPs were operated and maintained in such a way as to generate power in the most optimal manner and minimise power purchase.
- the periodical maintenance of the HEPs was planned and carried out economically and effectively and renovation, modernisation and uprating programmes were carried out effectively.

Audit criteria

2.4 Audit criteria for the Performance Audit were derived from the following:

- Targets fixed by KSEBL for generation of power and approved by the Central Electricity Authority and the Kerala State Electricity Regulatory Commission (KSERC).
- Best Practices Guidelines for Renovation and Modernisation of Hydro Power Plants by Central Electricity Authority.
- Central Electricity Authority (Technical Standards for construction of Electrical Plants and Electrical Lines) Regulation, 2010.
- Central Electricity Authority (Safety Requirements for Construction, Operation and Maintenance of Electrical Plants and Electric Lines) Regulations, 2011.
- Guidelines for Submission of Proposals for Revision of Design Energy of Hydro Electric Stations (2004) issued by the Central Electricity Authority.

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[17] One Megawatt is the equivalent of ten lakh (one million) watts.
[18] Extension schemes of Kuttiyadi and Neriamangalam HEPs were not considered as separate HEPs.
[19] HEPs with capacity above 25 MW.
[20] HEPs with capacity below 25 MW.

- Renovation, Modernisation and Uprating programs planned and scheduled by KSEBL and Regulations issued by KSERC in this regard.
- Central Electricity Regulatory Commission (Terms and Conditions of Tariff) Regulations.
- Manual on Renovation, Modernisation, Uprating and Life Extension of Hydropower Plants issued (February 2005) by Central Board of Irrigation and Power.
- Maintenance and Repair Schedules and Residual Life Assessment Study Reports.
- Board Orders, Directions/ Circulars *etc*. relevant to the topic.
- Agenda and Minutes of meetings of the Board of Directors and Core Committee.
- Investigation Reports/ Reports of Vigilance Wing of KSEBL.
- Stores Purchase Manual issued by Government of Kerala and General Conditions of Contract of KSEBL.
- Cost Audit Reports and Internal Audit Reports.

Audit methodology

2.5 The methodology adopted for attaining the audit objectives with reference to audit criteria consisted of explaining the audit objectives to top management of KSEBL/ Government of Kerala (GoK), scrutiny of records of KSEBL, analysis of data with reference to the criteria and issue of audit requisitions and queries. An Entry Conference was held in May 2019 with the KSEBL/ GoK wherein the scope and objectives were discussed. Field audit involving scrutiny of records was conducted during May to October 2019. The draft Performance Audit Report was issued to GoK/ KSEBL in May 2020 and an Exit Conference for discussing the Report with GoK/ KSEBL was held in September 2020. KSEBL furnished (August/ October 2020) its reply which was duly incorporated, while the replies from GoK were awaited (November 2020).

Acknowledgement

2.6 Audit acknowledges the cooperation and assistance extended by the Management and staff of KSEBL in the conduct of this Performance Audit.

Audit findings

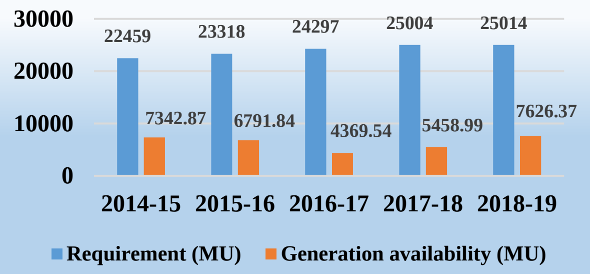
2.7 The findings of the Performance Audit are discussed in the succeeding paragraphs.

2.8 Performance of HEPs

Generation of power *vis-à-vis* requirement for power

2.8.1 The requirement for power *vs.* generation of power in the State (including generation of power by private generators) during 2014-15 to 2018-19 is shown in the **Figure 2.1**.

Figure-2.1: Requirement *vs.* Generation of power



The gap between the requirement for power and the generation of power in the State ranged between 67 to 82 *per cent*.

In order to bridge this gap, KSEBL purchased power from Central Generating Stations, Independent Power Producers, power exchange and traders. **Table 2.1** shows the details of generation of power by KSEBL, purchase from other sources along with average cost of purchase and generation of power.

Table 2.1: Details of generation and purchase of power

Particulars	Unit	2014-15	2015-16	2016-17	2017-18	2018-19
Generation by KSEBL[21]	Million Unit (MU)	7,301.00	6,753.38	4,339.93	5,474.47	7,577.02
Purchase of power		15,031.44	16,448.36	19,734.92	19,426.74	18,046.57
Total power supplied		22,332.45	23,201.75	24,074.85	24,901.21	25,623.59
Generation as a percentage of power supplied	*per cent*	32.69	29.11	18.03	21.98	29.57
Average cost of generation	(₹/kWh)	0.80	0.67	1.03	0.92	0.59
Average cost of purchase[22]	(₹/kWh)	3.61	3.25	3.75	3.87	4.19

(Source: Data furnished by KSEBL and Cost Audit Report of KSEBL)

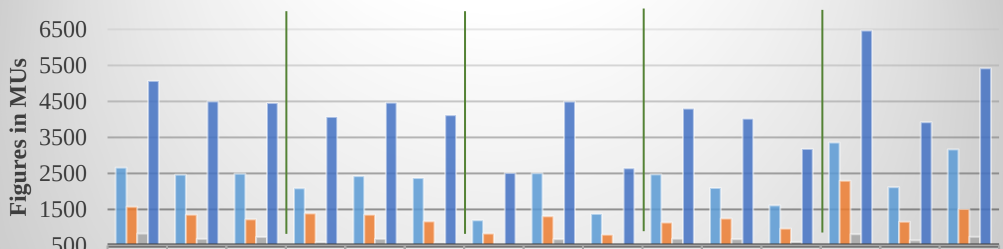
From the table above, it can be seen that KSEBL was able to generate only 18.03 *per cent* to 32.69 *per cent* of its annual requirement from its own sources. The gap between generation and demand was made up by the purchase of power at an average annual cost ranging from ₹3.25 to ₹4.19 *per unit* during the period covered in audit while the average cost of generation ranged from ₹0.59 to ₹1.03 *per unit.*

[21] Excluding Auxiliary Consumption, *i.e.*, the fraction of the power generated in a power house which is consumed by power generating equipment and their auxiliaries such as fans, motors *etc*.
[22] As per Cost Audit Report.

Generation targets and achievement

2.8.2 KSEBL fixed annual targets for generation of power and the same were approved by the Central Electricity Authority (CEA). The targets fixed and the actual generation there against in respect of Idukki, Sabarigiri and Kuttiyadi HEPs during 2014-15 to 2018-19 were as shown in **Figure 2.2**.

Figure-2.2: Generation Target vs. Actual



	2014-15			2015-16			2016-17			2017-18			2018-19		
	Inflow of water	Generation Target	Actual Generation	Inflow of water	Generation Target	Actual Generation	Inflow of water	Generation Target	Actual Generation	Inflow of water	Generation Target	Actual Generation	Inflow of water	Generation Target	Actual Generation
Idukki	2662	2465	2493	2086	2427	2373	1200	2505	1379	2475	2096	1611	3357	2119	3166
Sabarigiri	1575	1354	1225	1388	1354	1169	831	1312	798	1136	1250	969	2297	1159	1511
Kuttiyadi	830	682	738	593	682	576	480	676	465	690	676	601	812	644	740
Total	5066	4501	4456	4067	4463	4118	2511	4493	2642	4300	4022	3181	6467	3922	5417

(Source: Data furnished by KSEBL)

It can be seen that:

- Idukki HEP achieved the target only in 2014-15 and 2018-19. In 2015-16 and 2016-17, the HEP generated more power than the actual inflow of water during the year by utilising the water balance from the previous years. The power generation in 2017-18 was 1,611.10 MU only, despite the inflow of water for generation of 2,475 MU of power.
- Sabarigiri HEP could achieve the target only in 2018-19. The actual generation in 2014-15 and 2015-16 was less than the target, despite sufficient inflow of water. In 2016-17 and 2017-18, the HEP was not able to generate power even for the actual inflow of water.
- Kuttiyadi HEP achieved the annual target only in 2014-15 and 2018-19. In 2017-18, the generation was 601 MU of power only despite the water inflow for generation of 690 MU of power. But in 2015-16 and 2016-17 generation of power was lower than the actual inflow of water.
- The total generation of power by the three HEPs, however, indicated that these HEPs could not achieve the targets in four years. The shortfall was significantly higher in 2016-17 as the total generation was only 59 *per cent* due to deficit monsoon. On the other hand, the total generation exceeded the target by 38 *per cent* in 2018-19 due to heavy rainfall.

KSEBL replied (August 2020) that the achievement of HEPs against a fixed target changed due to various reasons such as inflow of water, availability of power from central stations and other States, demand, grid conditions, price of external power *etc*. Further, as the power purchase was based on Availability Based Tariff (ABT)[23], all the units were not utilised continuously even in peak hours and the units were often kept under cold reserve[24].

The reply was not tenable. As shown in **Figure 2.2**, HEPs could not achieve the targets despite availability of sufficient water. Further, the cost of generation from HEPs during 2014-15 to 2018-19 ranged between ₹0.67 to ₹1.03 *per unit* which in any case was lower than the cost of purchase from other sources.

Plant Load Factor

2.8.3 Plant Load Factor (PLF) in respect of a generating station refers to the ratio between actual generation and maximum possible generation at installed capacity. It indicates the output efficiency of a generating station. The actual PLF of the HEPs in comparison with their respective design PLF for the period 2014-15 to 2018-19 is given in **Table 2.2**.

Table 2.2: Details of design and actual plant load factor of HEPs

HEP	Design PLF	Actual PLF (*per cent*)					
		2014-15	2015-16	2016-17	2017-18	2018-19	Average
Idukki	35.92	36.50	34.62	20.68	23.58	46.35	32.35
Sabarigiri	51.00	17.44	16.65	20.18	13.80	21.51	17.92
Kuttiyadi	28.72@	37.46	29.22	11.36	30.47	37.53	29.21

(Source: Data furnished by KSEBL)

@ Weighted average design PLF of Kuttiyadi HEP, Kuttiyadi Extension Scheme and Kuttiyadi Additional Extension Scheme.

It can be seen from the above that while Idukki and Kuttiyadi HEPs could not achieve the design PLF in three out of five years and in one out of five years respectively, Sabarigiri HEP failed to achieve the design PLF in all the five years. The maximum PLF achieved by Sabarigiri HEP was 21.51 *per cent* only against the design PLF of 51.00 *per cent.*

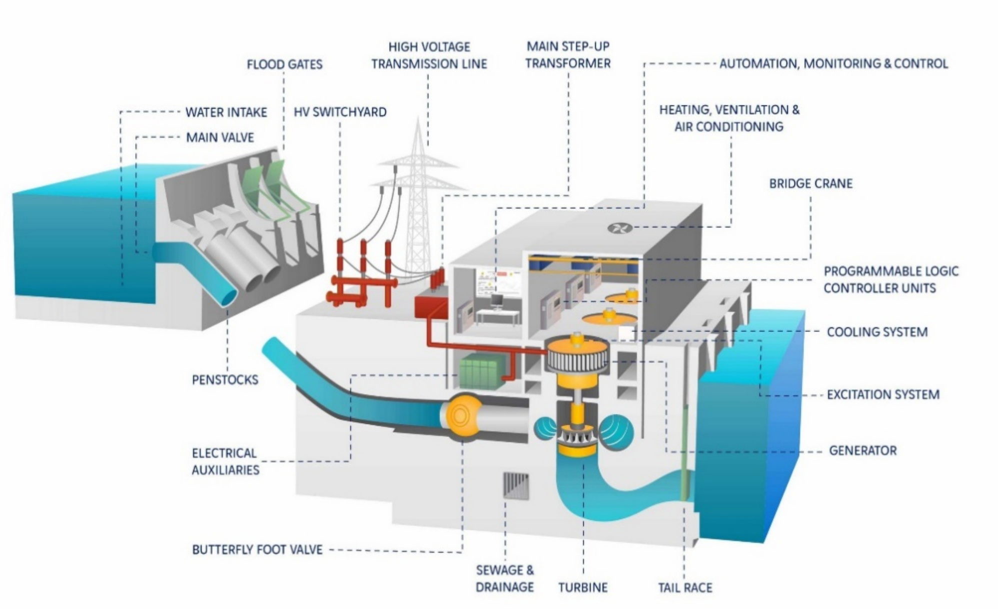
Audit observed that the generation capability of the HEPs and their PLF were affected due to the issues discussed in ***Paragraphs 2.8.4 to 2.8.9*** below. As a result, the HEPs suffered generation loss of 496.92 MU during the period from 2014-15 to 2018-19 and KSEBL incurred additional expenditure of ₹145.59 crore for purchase of power to make up the shortage in generation. The extra expenditure towards procurement of power was calculated at ₹2.93 per unit, being the average cost of power purchase per unit (₹3.73) during 2014-19, less the average cost of hydel generation (₹0.80) during the period. Since hydroelectric power is the cheapest and the most environmental friendly, it should be ensured that there is no shortfall in achievement of generation targets and PLF on account of controllable reasons.

[23] Availability Based Tariff (ABT) is a frequency based pricing scheme adopted in Indian power sector.

[24] Cold reserve in a power system is that reserve capacity which is available for service but normally not ready for immediate loading.

The important technical terms featured in this Report have been explained in the footnotes. A general presentation of a hydropower plant is given in the **Figure 2.3:**

Figure 2.3: General layout of a hydropower plant



Non-adherence to hydro generation policy

2.8.4 KSEBL follows a policy of conserving the water in reservoirs with large storage capacity such as Idukki, Pampa-Kakki, and Kakkayam during the monsoon months (June to November) in order to utilise the same to the maximum during the summer months (March, April and May) when the power purchase costs are high.

The power generation of Idukki, Sabarigiri and Kuttiyadi HEPs and power purchases in the summer months during 2016 to 2019[25] was analysed from the data provided by the State Load Dispatch Centre (SLDC) of KSEBL. Audit selected 22,080 blocks of 15 minutes' duration in the evening peak hours (18:00 to 23:00) of summer months and observed that in respect of 7,595 blocks (*i.e.* in 34.39 *per cent* blocks) power import exceeded the quantity scheduled for each block. It transpired that despite availability of adequate water in the reservoirs and availability of machines for meeting the additional requirement of power in the identified blocks, KSEBL did not step up the generation from these HEPs. Thus, though the water was conserved during monsoon, it was not used to the maximum during summer which was not in line with KSEBL's policy. Adherence to the generation policy would have reduced the import of power by 86.40 MU during the peak hours in the summer months of 2016 to 2019 for which KSEBL incurred an additional expenditure of ₹25.31 crore.

[25] SLDC provided data from 2016 only since the revamped Unified Load Despatch and Communication System was operationalised from January 2016.

KSEBL stated (August 2020) that the SLDC directs all the major generating stations to put the units in service based on various factors and all the units were not continuously used even in the peak hours during summer season as they were kept as cold reserve.

The reply was not tenable. SLDC is one of the operating units of KSEBL and expected to adhere to its policies while scheduling generation/ import with a view to minimise the cost of power purchase. Audit has considered those units which were in operation (excluding the units in cold reserve) during the peak hour blocks and observed that those were operated at less than the average generation.

Delay in replacement of pumps

2.8.5 Under the Sabarigiri Augmentation Scheme (1981), KSEBL set up a pump house at Kochu Pamba equipped with four turbine pumps of 235 kW capacity each. The pump house is to operate three pumps at a time to pump 14 MCM of water to generate 22.58 MU of power *per annum* from Sabarigiri HEP.

Due to long years of service coupled with obsolete switching arrangements and non-availability of transformer protection, only one pump could be operated at a time since December 2012. A temporary arrangement by providing one more pump was put in place. Since the remaining two pumps needed major repair, the Assistant Executive Engineer concerned proposed (December 2012) to replace the pumps in a phased manner. As per the estimate report (May 2015) for renovation of the pump house which included replacement of pumps, the new pumps would be operated for at least 7,000 hours during monsoon every year and would generate 12.20 MU of power. After deducting 1.40 MU towards power consumption by the pumps, there would be a net power generation of 10.80 MU per year.

Audit observed that though the pumps were experiencing problems since 2012 KSEBL invited tender for renovation of the pump house only in November 2016. The work order was finally placed in August 2019 only with the completion of works by April 2020. There was considerable delay in finalising the design of the pumps as the design was modified six times during January 2013 to August 2015. Though technical sanction for the works was accorded in October 2015, there was unexplained delay of 12 months for tendering the works. KSEBL took further 10 months for finalising the tender and to award the works.

Details of operations of the pump house from 2014-15 to 2018-19 indicated that two pumps were operated for eight months and one pump for 11 months in place of three pumps at a time. The quantity of water pumped during this period was 15.21 MCM which resulted in generation of 24.53 MU of power. However, renovation of pump house without any delay would have led to a total generation of 54 MU of power. Thus, there was a loss of generation of 29.47 MU of power during 2014-19 which also led to additional expenditure of ₹8.63 crore for procurement of alternate power.

KSEBL replied (August/ October 2020) that the pumps and panels were custom-made and the manufacturers could not supply such products to suit the requirements of KSEBL. Hence, there was delay in finalising the design of pumps. The tendering work was delayed as it was very difficult to get contractors for carrying out the work due to geographical terrain of the area. There was no spillage of water reported from

Kochu Pampa except in the heavy rain year of 2018-19 and it would have been a loss to KSEBL if water had been pumped into the dam. Hence, there was no energy loss due to non-installation of new pumps.

The reply was not acceptable. The proposal was for renovation of an existing pump house along with replacement of old pumps. Hence, the time taken (32 months) for finalising the design was not justified. Non-availability of contractor for undertaking the works was also not convincing as KSEBL completed the tendering process within three months when it retendered the works. Audit did not comment upon the spillage of water and associated generation loss, but highlighted the extra expenditure due to non-generation of electricity due to delay in replacing the old pumps.

Delay in rectifying defect due to bifurcation of penstock

2.8.6 Kuttiyadi HEP (3 units of 25 MW each) was commissioned in 1972. Kuttiyadi Extension Scheme (KES) with a capacity of 50 MW was commissioned in 2001 by bifurcating the existing penstock[26] into two penstocks, one supplying water to the three units of 25 MW each of Kuttiyadi HEP and the other supplying water to the 50 MW unit of KES. In this regard, Audit observed that:

- After the introduction of the penstock of KES, the runner buckets[27] in the Pelton turbine[28] of the old units started developing severe pitting[29] and frequent bucket cracking during the year 2003. This was attributed to the head loss[30] and turbulence in the water at the bifurcation point of the penstock. KSEBL subsequently found that when the three units of Kuttiyadi HEP were run at reduced maximum loads, the severity of pitting reduced. Therefore, KSEBL decided (August 2011) to operate the three units at a reduced combined load of 65 MW instead of 75 MW.

- The problem was first noticed in 2003. During 2003-04 to 2008-09, regular repair works were carried out to rectify the damage caused to the runner by pitting. To avoid further breakdowns and repair, the generation from Units 2 and 3 was reduced from August 2011 onwards. KSEBL engaged a consultant to conduct detailed study of the combined water conducting system only in March 2012. The consultant concluded (June 2014) that taking a branch penstock from the main penstock led to flow instabilities in the downstream from the bifurcation point of the penstock. Hence, the consultant

[26] A penstock is an enclosed pipe that delivers water to a hydro turbine from the reservoir.

[27] A Pelton turbine consists of a runner, which is a circular disc on the periphery of which a number of buckets are mounted with equal spacing between them.

[28] Pelton Turbine is a tangential flow impulse turbine in which the pressure energy of water is converted into kinetic energy to form high speed water jet and this jet strikes the wheel tangentially to make it rotate.

[29] Pitting is a form of extremely localised corrosion that leads to the creation of small holes in the metal.

[30] Head loss refers to the totality of energy losses due to the length of a pipe and those due to the function of fittings, valves and other system structures.

recommended an additional penstock from the dam to the bifurcation point so as to create an independent water conducting system for the new unit.

- KSEBL initiated corrective measures in June 2017 as suggested by the consultant, after a delay of three years. Though the consultant had recommended the corrective measures in 2014, the work for laying the penstock is still under tendering (October 2020). Rather than taking up this work separately, this was clubbed with RMU of Kuttiyadi HEP and delayed as detailed in ***Paragraph 2.10.4***.
- During the period from 2014-15 to 2018-19, KSEBL suffered generation loss of 178.70 MU due to the reduced utilisation of generating units at the Kuttiyadi HEP by 10 MW. This also led to avoidable expenditure of ₹52.36 crore towards procurement of power to make up the reduced generation during this period.

KSEBL stated (October 2020) that the existing penstock of water conducting system of Kuttiyadi HEP was bifurcated to complete the project within a short span of time and to avoid delays in obtaining environmental clearance. A proper solution could be evolved only through detailed analysis of the problems and evolving a pragmatic solution was time consuming. Since there was no spillage from reservoir reported except during 2018-19, the 10 MW reduction has reserved water for use in summer seasons.

The reply was not acceptable. Audit highlighted the avoidable delay in resolving the technical issue noticed in the penstock. While noting KSEBL's contention that detailed study was required for evolving a suitable solution, a period of 17 years for addressing the technical issue was detrimental to the financial interests of KSEBL and hence not justified. Audit did not comment upon the spillage of water and associated generation loss, but highlighted the reduction in generation capacity and consequent purchase of power from other sources incurring extra expenditure.

Runner erosion due to construction of weir across tail race

2.8.7 As per Regulation 33 (11) of the Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010, Pelton turbine shall be installed with its centreline at a height of minimum three meters above the maximum tail water level or as per the recommendations of the manufacturer.

KSEBL commissioned Kuttiyadi Additional Extension Scheme (KAES) with a capacity of 100 MW (2 x 50 MW) in October 2010. To effectively utilise the tail race waters of KAES, KSEBL implemented Kakkayam Small Hydro Electric Project (Kakkayam SHEP) during December 2012 to February 2015. As part of Kakkayam SHEP, a weir[31] of 1.29 meter height was constructed across the tail race

[31] A weir or low head dam is a barrier across the width of a river that alters the flow characteristics of water and usually results in a change in the height of the river level.

channel[32] of KAES approximately 80 meters away from the runner housing[33]. In this regard, Audit noticed that:

- Severe runner erosion was noticed on the rear side of the buckets in the Pelton turbine of Unit 2 of KAES from April 2013. KSEBL found that the tail race water level below the runner pit in the Pelton turbines of Unit 1 and 2 of KAES increased beyond the maximum prescribed level due to the construction of the weir which led to lack of proper aeration in the runner housing. In order to protect the runner from further damage, KSEBL decided (March 2015) to restrict the generation capacity from 100 MW to 80 MW.
- KSEBL consulted Bharat Heavy Electricals Limited (BHEL), the Original Equipment Manufacturer (OEM), to rectify the defects in the runner housing. After inspecting the site, BHEL informed that the runner erosion was due to the sub-atmospheric condition inside the runner housing caused by the lack of proper aeration through the tail race after the construction of the weir. BHEL also informed that the weir was constructed without taking their consent and also without considering its consequences on the health of the generation units of KAES in violation of the contract.
- KSEBL took five years to finally resolve (March 2018) the issue by providing aeration pipes inside the runner pits while it suffered generation loss of 133.80 MU of power from April 2015 to March 2018. During this period, KSEBL incurred an extra expenditure of ₹39.20 crore towards procurement of power to compensate this generation loss.

KSEBL replied (August 2020) that there was no delay in attending the problem. Such problems could only be solved by some detailed analysis and step by step method. KSEBL contended that no loss was incurred as the unutilised portion of water could be used during peak summer period when the cost of power was high. There was no spillage in Kuttiyadi dam during the period 2015-2018.

The reply was not acceptable as KSEBL took five years to solve the aeration problem associated with runner housing of KAES. Also KSEBL constructed the weir across the tail race without consulting the OEM of KAES regarding tail race water level. Due to reduction in generation capacity, KSEBL resorted to purchase of power and incurred additional expenditure.

Delay in completing the work of power channel gates

2.8.8 Kuttiyadi Tail Race (KTR) power house (3.75 MW) under the Kuttiyadi HEP consisting of three units of 1.25 MW each was commissioned during June 2008 to October 2009. The project uses the water discharged from the Kuttiyadi HEP (Unit 1, 2 and 3) and KES (Unit 4). An open power channel of 600 meter length is connecting the common tail race of Kuttiyadi HEP and KES and the fore bay tank[34]

[32] Tail race is an open channel made up of reinforced concrete or a pipeline to carry away the water discharged from the turbine of a generating station after power is produced from the water.

[33] Runner housing is the enclosure that surrounds the runner which is the rotating part of the turbine that converts the energy of falling water into mechanical energy.

[34] The forebay tank forms the connection between the channel and the penstock and also serves as reservoir at the head of the penstock that carries water to the turbine.

of KTR power house. The water flow through the channel is controlled by three vertical shutters situated near Kuttiyadi HEP while a surplus channel is used to divert excess water from the fore bay tank of KTR.

In July 2010, the generating units at the KTR tripped and the water level in the power channel rose due to insufficient surplus channel. The power channel walls also broke due to the excess water pressure and water spilled over to the nearby properties. This was due to practical difficulties in closing the third shutter in the power channel as a person was required to travel about a kilometre to close the same. Since then, one of the vertical shutters was fully inserted in the power channel to reduce the water flow, the second shutter was placed in hanging position to adjust the flow according to the load conditions and maximum generation from KTR units was limited (July 2010) to 2.5 MW. In order to solve the difficulty in closing the power channel shutters, KSEBL accorded (September 2015) sanction for combining the three pieces of power channel shutters into one single piece at an estimated cost of ₹0.15 crore.

Though an estimate was prepared and approved in September 2015, KSEBL was yet (March 2020) to finalise the rectification work. There was lack of coordination between the Civil Construction and Generation wings in KSEBL which resulted in non-finalisation of technical design for the rectification works. As per the estimate for this work, completion of the rectification work would result in a minimum load increase of 0.5 MW. The non-execution of the rectification works, therefore, resulted in generation loss of 10.95 MU during 2014-15 to 2018-19 due to reduced utilisation of capacity at the KTR. This also led to extra expenditure of ₹3.21 crore for procurement of power during this period.

KSEBL replied (August 2020) that the maximum generation of KTR was limited to 2.5 MW due to problems associated with the power channel gates. The proposal for solving these problems by joining the two gates was being examined. A trial run was conducted in February 2020 for analysing the level of the channel and water surge, after which, Chief Engineer, (Civil Construction, North) has formulated a proposal for strengthening the channel and the report was yet to be finalised.

The reply was not acceptable as the difficulty in closing the power channel gates was persisting since July 2010 and no tangible measures were taken for its rectification. This also reduced the generation of power by 0.5 MW. Audit noticed that the Deputy Chief Engineer (Generation) had submitted a detailed proposal for strengthening the power channel in July 2010 to the Chief Engineer (Civil Construction). Hence, the fact that the power channel required strengthening was known to KSEBL even before the trial run in February 2020.

Insufficient power evacuation lines

2.8.9 The total installed capacity of Kuttiyadi HEP was enhanced to 225 MW with the commissioning of KAES (100 MW) in 2010. Power evacuation from Kuttiyadi HEP is carried out through four 110 kV feeders, *viz*., two feeders cater to Kozhikode side and other two towards Kannur side. The conductor current carrying capacity of each feeder was 343-Ampere. But, in view of the weak jumper[35] connection and other weak points in the feeders, the feeders were loaded only up to 330-Ampere. In order to evacuate the power generated from KAES and to improve the current carrying capacity of the feeders, KSEBL approved (March 2007) works for construction of transmission facilities[36] at a cost ₹17.22 crore.

Though the construction of transmission facilities were awarded during October 2008 to May 2009, the works were stopped due to litigation from the public against the drawal of line through the proposed route. The disputes were settled and the routes were cleared by the end of 2011. The contractor did not resume the work demanding rate escalation which KSEBL rejected and short-closed (July 2012) the contract. The work, though retendered in February 2014, was not awarded as the contractor quoted 143.38 *per cent* above the estimate. The execution of the works remained at standstill thereafter.

Despite KSEBL considering various options such as combining the construction of transmission facilities in one package, assigning the works to other separate field offices and constructing new transmission facilities *etc*., the works did not progress further. This indicated that KSEBL could not firm up a technically feasible proposal for construction of the lines and other facilities even though it was incurring considerable loss by way of reduced generation from the Kuttiyadi HEP.

As a result, the peak load generation at Kuttiyadi HEP was reduced by 50 MW during off-monsoon period and by 10 MW during monsoon period which necessitated procurement of power from other sources as under:

- *During off-monsoon period (October to May)* – underutilisation of capacity of 50 MW for three hours per day led to generation loss of 10.47 MU of power *per annum* (based on combined PLF of Kuttiyadi HEP). This resulted in extra expenditure of ₹15.34 crore for procurement of power during the period covered in audit (2014-19).
- *During monsoon period (June to September)* – underutilisation of capacity of 10 MW for three hours per day led to generation loss of 1.05 MU of power *per annum* (based on combined PLF of Kuttiyadi HEP). This resulted in extra expenditure of ₹1.54 crore for procurement of power during the period covered in audit (2014-19).

KSEBL replied (August 2020) that the conductor of two feeders towards Kozhikode side were replaced with high capacity conductors in May 2019 and no transmission line constraint was experienced at present. The re-conductoring of the two feeders towards Kannur side was in progress. KSEBL added (October 2020) that the delay occurred mainly due to the litigations and time taken for repeated tendering due to escalation in rates. Though there were line constraints, Kuttiyadi HEP was able to load up to 210 MW by splitting the buses and putting the lines in radial mode while

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[35] A jumper is a tiny metal connector that is used to close or open part of an electrical circuit.

[36] Construction of 110 kV Multi-Circuit line from Kakkayam to Pattanippara and 100 kV Double-Circuit line from Pattanippara to 220 kV Substation Vadakara, including construction of two 100 kV feeder bays at 220 kV Substation Vadakara.

the maximum capacity could be obtained by putting all machines into operation was roughly 215 MW. Hence, the loss calculated by Audit was exorbitant.

The reply was to be viewed against the fact that KSEBL could not fully solve the power evacuation issues even after 12 years despite incurring additional expenditure of ₹16.88 crore during 2014-19 for procurement of power. For assessing the impact of non-availability of evacuation lines, Audit adopted the reduction in generation capacity as assessed by KSEBL and hence, there was no basis for stating that the extra expenditure stated by Audit was exorbitant.

Control and monitoring of power stations

2.8.10 The State Load Dispatch Centre (SLDC) is the apex body to ensure integrated operation of the power systems in the State by monitoring grid operations through optimum scheduling and despatch of electricity. The SLDC controls the output from the various generating stations of KSEBL as per the approved annual generation plan and taking into account the water availability in HEPs on a daily basis. The SLDC also schedules and executes the import/ export of power and interaction with the Regional/ National Power Grid. The operations at the individual power stations are controlled by the respective operators under the supervision of superior officers and the SLDC. Control over the generators/ turbines is exercised through the Supervisory Control and Data Acquisition (SCADA) software which is interfaced with the embedded software in the generating units.

Deficiencies in SCADA upgradation

2.8.10.1 KSEBL awarded (January 2017) a work for upgrading the SCADA software used in the Sabarigiri HEP to Andritz Hydro Private Limited at ₹5.25 crore stipulating completion of the work by December 2017. The contractor completed all works except installation of optical fibre communication ring with various SCADA equipment (October 2019).

KSEBL decided to upgrade the existing SCADA software as it was outdated. Audit observed that the SCADA software upgraded by the contractor is compatible with Windows 7 platform only, though the latest version of Microsoft Windows 10 platform was available since July 2015. Thus, KSEBL did not ensure that the software upgradation was compatible with the latest Microsoft Windows platform. It was also noticed that the product support for Windows 7 ended in January 2020 whereas the product support for Windows 10 would be available up to 2025. Hence, KSEBL might have to opt for another upgradation in the near future.

KSEBL replied (August 2020) that it opted for Windows 7 as it was bug-free and stable compared to the new versions.

The reply was not acceptable as the Guidelines for Protection of Critical Information Infrastructure issued (January 2015) by National Critical Information Infrastructure Protection Centre[37] stipulated that outdated or obsolete technology should be avoided as far as possible and facility of updation and patching should be ensured.

[37] National Critical Information Infrastructure Protection Centre is the nodal agency notified (January 2014) by Government of India for protection of Critical Information Infrastructure.

Recommendation 2.1: Early action may be taken to rectify design defects and problems affecting generating capabilities of HEPs to prevent recurring generation losses.

Recommendation 2.2: Hydel resources may be utilised to the maximum possible extent to meet unforeseen surges in demand in line with the policy of KSEBL.

Recommendation 2.3: Lack of coordination among functional wings within KSEBL which led to delays in addressing critical operational issues needs to be addressed on priority.

Maintenance of HEPs

2.9 As per the Best Practices in Operation and Maintenance of Hydro Power Stations of the CEA, the downtime of individual generating unit/ plant should be minimum and the operational reliability of the generating units shall be such that, whenever the grid demands, it should be available for generation.

Plant Availability Factor

2.9.1 The Plant Availability Factor (PAF), a ratio of actual hours operated to maximum possible hours available during a period, is an indication of the efficiency at which the maintenance and upkeep of the equipment of the HEP is carried out. As per GoI notification (30 March 1992), the norm for PAF of HEP is fixed as 90.00 *per cent*.

The PAF of Idukki, Sabarigiri and Kuttiyadi HEPs for the period 2014-19 is given in **Table 2.3**.

Table 2.3: Details of Plant Availability *vs.* norm in three HEPs

HEP	Norm (*per cent*)	Actual PAF (in *per cent*) as furnished by KSEBL					
		2014-15	2015-16	2016-17	2017-18	2018-19	Average
Idukki	90.00	87.49	89.64	89.53	76.89	76.66	84.04
Sabarigiri		80.10	79.81	85.67	84.19	78.71	81.70
Kuttiyadi		87.12	87.12	87.51	84.96	79.21	85.18

(Source: Data furnished by KSEBL)

It is observed that none of the three HEPs were able to achieve the norm of 90 *per cent* PAF during the period under review.

Detailed review of operation of the HEPs revealed that the PAF was affected by considerable amount of forced outages, improper and inefficient execution of maintenance of equipment, repeated accidents in the Idukki HEP *etc*. as discussed in the succeeding paragraphs.

Plant outages

2.9.2 Outage refers to the period when a power generating unit is not in operation. Outage can be either planned outage or forced outage. Planned outage is the scheduled removal of generating unit from service for inspection, maintenance or repair whereas forced outage is an immediate reduction in output or capacity of a generating unit by reason of an emergency or other causes beyond the control of the HEP. The quantum of forced outages, however, is directly related to the timeliness and quality of the maintenance activities. The status of outages in Idukki, Sabarigiri and Kuttiyadi HEPs is given in **Table 2.4**.

Table 2.4: Details of total and forced outages of HEPs during 2014-19

(*in hours*)

Name of HEP	2014-15		2015-16		2016-17		2017-18		2018-19	
	Outages		Outages		Outages		Outages		Outages	
	Total	Forced	Total	Forced	Total	Forced	Total	Forced	Total	Forced
Idukki	6,094	451	5,434	455	6,302	459	5,599	42	11,721	167
Sabarigiri	10,008	1,274	7,952	279	7,571	91	8,521	482	11,922	403
Kuttiyadi	6,672	270	6,676	128	7,020	74	7,910	67	NA	119

(Source: Data furnished by KSEBL)

While the percentage of forced outage in Idukki HEP ranged between 0.75 *per cent* and 8.37 *per cent* during the period covered in audit (2014-15 to 2018-19), the same in respect of Sabarigiri HEP ranged between 1.20 *per cent* and 12.73 *per cent.* In the case of Kuttiyadi HEP, the forced outage to total outages ranged between 0.85 *per cent* and 4.05 *per cent* during this period. During the period of forced outages, KSEBL could not generate 920.71 MU of power from the three HEPs and had to procure electricity from other sources for ₹269.77 crore during 2014-15 to 2018-19. Specific instances of long duration of forced outages are discussed in ***Paragraphs 2.9.5, 2.9.7.2 and 2.10.3.1***.

KSEBL replied (August 2020) that the assumption that during the period of forced outage KSEBL could not generate power need not be true always as the hydro generators have the inherent limitation of total generation limited to the inflow and effective storage.

The reply was not acceptable. Forced outage caused loss of generation to KSEBL as the units were taken out of the grid. Further, KSEBL did not provide any details related to forced outages which occurred when the units could not be operated due to limited inflow/ storage of water.

Annual Maintenance of HEPs

2.9.3 KSEBL follows the practice of undertaking annual maintenance of HEPs[38] during monsoon months (June to November) in order to ensure the plant availability during summer months (March to May). The Idukki, Sabarigiri and Kuttiyadi HEPs have six generating units each. One generating unit requires annual maintenance for 30 days. Hence, each HEP has to undertake six annual maintenances every year and

[38] In the case of Kuttiyadi HEP, the annual maintenance was undertaken during off-monsoon period so as to reduce the water spillage in the dam.

30 annual maintenances in the five-year period. Scrutiny of records related to annual maintenance of three HEPs during 2014-19 revealed the following:

- Five cases of annual maintenance in Kuttiyadi were not carried out.
- KSEBL did not comply with the policy of undertaking maintenance of the HEPs in the monsoon months. Out of 30 cases of annual maintenances of each HEP, nine cases in Idukki HEP and 13 cases in Sabarigiri HEP were carried out in off monsoon months.
- KSEBL carried out annual maintenance works in excess of the prescribed period of 30 days. The excess days ranged up to 12 days in the case of Idukki HEP, 183 days in the case of Sabarigiri HEP and 27 days in the case of Kuttiyadi HEP.

Undertaking maintenance works in off monsoon periods and also taking more days beyond the prescribed quantum of 30 days were due to undertaking other repair works, which ought to have come under forced outages, along with the annual maintenance. Further, non-availability of the spares also resulted in the excess days of annual maintenance.

KSEBL replied (August 2020) that annual periodic maintenance works were carried out as per the concurrence and strict monitoring of SLDC, necessitating shifting of maintenance schedules. Further, the annual maintenance works were extended to accommodate some special works and in some specific cases clubbed with forced shutdown maintenance works/ other essential maintenance works in consultation with SLDC.

The reply was not acceptable. The reply was silent on the reasons for non-conduct of annual maintenances in the case of Kuttiyadi HEP. An Expert Committee of KSEBL which investigated two recent accidents that occurred in Idukki HEP in January/ February 2020 recommended (March 2020) that the scheduled maintenances should never be compromised under any circumstances or altered at any cost. Clubbing of the annual periodic maintenance works of HEPs with forced shutdown maintenance works or other required essential maintenance works was not acceptable, as these should invariably be shown under forced outages.

Excess auxiliary consumption

2.9.4 Regulation 46 (2) (a) of the KSERC (Terms and Conditions for Determination of Tariff) Regulations, 2014 provides for the auxiliary consumption[39] for the major generating stations of KSEBL. The normative auxiliary consumption of the three HEPs as a percentage of gross generation and the actual auxiliary consumption during the period 2014-15 to 2018-19 were as given in the **Table 2.5** below.

[39] Auxiliary consumption is the fraction of the power generated in a power house which is consumed by power generating equipment and their auxiliaries such as fans, motors *etc*.

Table 2.5: Details showing auxiliary consumption of the HEPs

HEP	Norm (*per cent*)	Actual auxiliary consumption (in *per cent*)					
		2014-15	2015-16	2016-17	2017-18	2018-19	Average
Idukki	0.53	0.45	0.41	0.55	0.35	0.35	**0.42**
Kuttiyadi	0.22	0.35	0.38	0.43	0.35	0.25	**0.35**
Sabarigiri	0.24	0.32	0.33	0.39	0.35	0.25	**0.33**

(Source: Data furnished by KSEBL)

During the period 2014-15 to 2018-19, the auxiliary consumption in the case of Idukki HEP was within the norms except during 2016-17, while the auxiliary consumption recorded at Sabarigiri and Kuttiyadi HEPs exceeded the norms throughout the period. Consequently, the HEPs consumed 36.47 MU of power towards auxiliary consumption during this period as against 26.81 MU of power as per the norm. The excess auxiliary consumption during the period, thus, worked out to 9.66 MU of power which led to purchase of power amounting to ₹2.83 crore.

Audit also observed that KSERC, while approving the truing up petition of KSEBL for the year 2015-16, disallowed 7.44 MU of power from the auxiliary consumption claimed by KSEBL as it was in excess of the norms. In the case of truing up petition for the year 2016-17, even though the auxiliary consumption by the generating stations of KSEBL was in excess of the norm, KSERC allowed the actual consumption due to the monsoon shortfall during the year. The truing up petitions for the year 2014-15 was pending approval of KSERC while KSEBL filed the truing up petitions for the years 2017-18 and 2018-19 in December 2019 and March 2020 respectively as there was delay in finalisation of financial statements for these years. In the truing up orders, KSERC also observed that KSEBL did not furnish any clarification sought by it regarding the excess auxiliary consumption.

KSEBL replied (August 2020) that auxiliary consumption not only depended on annual generation but also on the total running hours of the generators irrespective of its load and also the power consumed by the equipment which were used, while the machines were in annual maintenance. Hence, the auxiliary consumption exceeded the normative value.

The reply was not tenable. KSERC fixed separate norms for each HEP which itself indicated that the specific working requirements and conditions of each HEP were taken into account while fixing the norm. The practical difficulties, if any, in achieving the norm should have been taken up with KSERC.

Accidents in Idukki HEP

2.9.5 Idukki HEP is an underground power station and constitutes 37.88 *per cent* of the total hydel capacity of KSEBL. Therefore, timely and efficient upkeep of systems and equipment of the generating units to avoid accidents is of utmost importance. Audit, however, noticed that a series of accidents occurred in Idukki HEP which led to long duration of outages and consequent non-generation of electricity. Audit examined the accidents that occurred in Idukki HEP between 2011 and 2020 for assessing the reasons and remedial actions taken by KSEBL to avoid further occurrence. **Table 2.6** shows the details of accidents in Idukki HEP:

Table 2.6: Details of accidents in Idukki HEP

Date	Unit	Particulars	Main reason for accident	Other common reasons
20/06/2011	5	Flash over of 11 kV Potential Transformer and Lightning Arrester.	Failure of surge capacitors (surge capacitors failure)	1. Ageing of the equipment 2. Lack of proper maintenance 3. Lightning issues
03/11/2013	5	SF6 circuit breaker exploded	Faulty circuit breaker. (circuit breaker failure)	
28/04/2015	3	Explosion of 220 kV circuit breaker 3 and tripping of all six generators.	Inadequate making of breaker main contacts inside the interrupting chamber assembly (circuit breaker failure)	
20/01/2020	2	Explosion in 11 kV bus duct near exciter transformer	Loose connection in R phase bushing of excitation transformer to 11 kV tap bus	1. Ageing of the equipment 2. Lack of proper maintenance
01/02/2020	6	Explosion of surge arrester	Rapid degradation in the insulation of 11 kV Y phase surge capacitor and dislocation of the Y phase of the exciter transformer. (surge capacitors failure)	1. Ageing of equipment 2. Lack of proper maintenance

(Source: Accident investigation reports provided by KSEBL)

Audit noticed that after every accident, KSEBL appointed committees to investigate the reasons of the accidents and to suggest remedial measures. KSEBL, however, did not implement the recommendations of these committees as discussed below.

- The Committee that investigated the fatal accident of 2011 recommended (15 July 2011) implementation of condition monitoring diagnostic techniques[40] and periodical review/ modification of other station related maintenance practices. The Committee also recommended to form a Power Equipment Testing (PET) subdivision in all the Generation Circles to conduct half-yearly Tan delta[41] and insulation leakage (AC) current measurements of Lightning Arrester, Voltage Transformer, Surge Capacitor

[40] On-line diagnostic equipment shall be dedicated type for that critical equipment, the health of which is to be monitored continuously and includes dissolved gas analyser, winding resistance meter and frequency response analyser for transformers and reactors, capacitance and tan-delta measuring units for transformers, reactors and instrument transformers, circuit breaker analyser including dynamic contact resistance meter and leakage current monitor for surge arrester and relay testing kit.

[41] Tan δ or Tan Delta, also called Loss Angle or Dissipation Factor testing, is a diagnostic method of testing cables to determine the quality of the cable insulation.

and Bus Duct Insulators and to implement a disaster management scheme. The recommendations of the Committee, however, were not implemented (August 2019) by KSEBL. It was noticed that the subsequent accidents that occurred in January 2020 and February 2020 were due to the failure of equipment such as surge arresters/ capacitor and problems in the bus duct. The non-implementation of the recommendation regarding diagnostic techniques was to be viewed against the fact that the CEA regulations[42] required that diagnostic methods should be preferred over traditional time-based maintenance and diagnostic equipment should be provided to assess the health of various equipment.

- In the wake of fault of circuit breaker of Unit 6 in 2010, it was proposed to install new circuit breakers for Units 4 and 5 also. The circuit breakers were, however, replaced only after the explosion of the circuit breakers of Unit 5 in November 2013.
- The Vigilance Wing of KSEBL, after the accident in November 2013, recommended to increase the frequency of PETs from annual to quarterly basis. This was, however, not complied with. Though one PET was conducted in August 2014, it was incomplete as the closing time of the circuit breaker was not recorded. It is pertinent to mention that the accident which occurred on 28 April 2015 was due to failure of the circuit breaker.
- The repeated accidents due to failure of similar equipment also indicated that the committees which investigated accidents did not examine whether the recommendations given by the previous committees were complied with or not.

The above accidents led to prolonged outages and non-generation of power from Idukki HEP. During the period covered in audit, there were outages of 362.97 hours which led to non-generation of power and procurement of 16.95 MU of power from other sources incurring extra expenditure of ₹4.97 crore.

KSEBL replied (August 2020) that providing of diagnostic equipment could not have prevented the accidents. The recommendation of the committee regarding providing diagnostic testing could not be carried out in view of the age of the equipment. Formation of separate PET sub-divisions for each generation circle was being done. It was also added that other recommendations of the committees were being carried out.

The reply was not acceptable as the condition monitoring of equipment in the generating units was necessary to assess the health of the equipment. Inability to conduct diagnostic testing due to age of the equipment warrants immediate

[42] The Central Electricity Authority (Grid Standards) Regulations, 2010 and The Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electrical Lines) Regulations, 2010.

replacement of such equipment. Non-implementation of recommendations given by the committees in 2011 and 2013 was not justified.

Poor performance of circuit breakers

2.9.6 KSEBL replaced three numbers of 220 kV circuit breakers costing ₹0.39 crore, one circuit breaker each at Unit 2 and Unit 3 of Idukki HEP and the third one at Idukki-Udumalpet inter-State feeder, during August 2015 to October 2016. As per the purchase order, the materials were guaranteed for satisfactory performance for a period of 24 months from the date of receipt and defects, if any, noticed during this period were to be rectified/ replaced free of cost. Guarantee period of these circuit breakers expired in February 2017, May 2017 and April 2018 respectively.

Audit observed that all the three circuit breakers showed deviations of similar nature in the routine tests/ re-tests conducted (July 2016 to January 2019). These incidents occurred within four years of commissioning of the circuit breakers and also during the performance guarantee period though the supplier claimed trouble free operation for 10 years. KSEBL, however, did not take any steps to replace the defective equipment despite enabling provision in the purchase order. This carried the risk of further failures, apart from posing threat to the security and safety.

KSEBL replied (August 2020) that the matter was reported to the Chief Engineer concerned who was the agreement authority for taking up the matter with the firm.

The reply was not acceptable as KSEBL did not replace the defective equipment though deviations in performance of the circuit breakers were noticed since July 2016.

Health and safety

2.9.7 CEA issued (January 2010) the Central Electricity Authority (Safety Requirements for Construction, Operation and Maintenance of Electrical Plants and Electric Lines) Regulations, 2011 under Section 177 read with section 73(c) of the Electricity Act 2003.

Compliance to IS-18001 Certification

2.9.7.1 As per Regulation 4, a company which owns or operates or maintains electrical plants or electrical lines shall make safety an integral part of work processes to ensure safety for employees as well as visitors and shall obtain accreditation of electric plants and electric lines with IS-18001 certification[43] within two years from the date (January 2010) of coming into force of the Regulation. It was, however, observed that the three HEPs covered in audit were operated without obtaining IS-18001 certification for the last eight years.

KSEBL stated (August 2020) that IS-18001 certification as directed by CEA would be obtained.

[43] IS-18001, brought out by Bureau of Indian Standards, intends to assist the organisations to develop a systematic approach to management of Occupational Health and Safety (OH&S) in such a way as to protect their employees and others whose health and safety may be affected by the organisations' activities.

Landslide at HEPs

2.9.7.2 Regulation 9 provided for formulation of an on-site Emergency Management Plan within 90 days of the Regulation coming into force for dealing with probable emergencies[44] including landslide. As per Regulation 5 read with 4 (c), a site-specific Safety Manual shall be prepared in accordance with Schedule I(A), I(B) and II of the Regulation. Audit observed that:

- KSEBL prepared a Safety Manual as per Schedule I (A) which dealt with common issues for all types of power plants and Schedule II which prescribed safety features to be additionally covered in Safety Manual for Operation and Maintenance for the Idukki and Kuttiyadi HEPs. But KSEBL did not prepare on-site Emergency Management Plan and Safety Manual as per Schedule I (B) which was specifically meant for HEPs wherein preventive measures against landslides were also to be included.
- The Kerala State Disaster Management Authority (KSDMA) under Section 14 of the Disaster Management Act, 2005 published maps[45] (2010) indicating landslide susceptible zones in Kerala. As per these maps, Kakkayam dam, Kakki dam and power houses of Sabarigiri and Kuttiyadi HEPs are situated in proximity on either sides of high and medium hazard landslide susceptible zones. The penstock of Kuttiyadi HEP and the penstock from Kakki dam to the power house of Sabarigiri HEP also passes through the landslide susceptible zones.
- In August 2019, a landslide occurred in Kuttiyadi HEP site completely disabling Unit 4, 5 and 6 which could only be put back into operation between September and November 2019. KSEBL's failure to undertake landslide mitigation measures, despite repeated instances of landslides in nearby areas, led to forced shut down of these units for 3,704:22 hours and generation loss of 26.45 MU of power. This also led to extra expenditure of ₹7.75 crore for procuring power, apart from incurring ₹ five crore for restoration of these units.

KSEBL stated (August 2020) that a plant level disaster management group was formed in September 2019. KSEBL added (October 2020) that measures were being taken for constructing retaining walls which could mitigate the impact of landslides to some extent.

Non-reporting of outages to CEA

2.9.7.3 As per Regulation 8, HEPs are required to report accident cases of outages to CEA within 24 hours, whether or not any death or disablement is caused to any person.

Audit observed that HEPs, however, did not report the accident cases of outages to the CEA. Timely reporting of cases of accidents would have enabled CEA to decide

[44] Like fire, explosion, gas leakages, landslides, floods, earthquakes, storms, cyclones, hurricanes, and crisis situations arising in the event of strikes, terrorist threats, attacks and sabotages, bomb threats and explosions.

[45] https://sdma.kerala.gov.in/maps/

if investigation at the accident site was required and also to recommend remedial measures to prevent recurrences.

KSEBL accepted (August 2020) the audit observation and assured that future accidents would be reported to CEA within the prescribed time frame.

Replacement of Clophen-filled transformers

2.9.7.4 HEP utilises a portion of power generated by it for running other plant and systems used by it. The auxiliary transformers ensure correct voltage for all such equipment. The old auxiliary transformers installed in HEPs were filled with Clophen, a Poly Chlorinated Biphenyl (PCB)[46]. **Table 2.7** indicates status of Clophen filled auxiliary transformers in the HEPs.

Table 2.7: Status of Clophen-filled auxiliary transformers

HEP	Remarks
Idukki	There were ten Clophen-filled transformers, of which seven transformers were still continuing in service. The remaining three were taken out from service in 2000, tagged, labelled and kept in store, but yet to be disposed.
Sabarigiri	There were seven Clophen-filled transformers, of which four were replaced in 2016 and another two were removed from service in 2017. The remaining one transformer was still in service. Further, 2,000 litres of Clophen taken out from the dismantled transformers was filled in barrels and stacked separately.
Kuttiyadi	There were two Clophen-filled transformers. While one transformer was taken out from service in December 2017 and moved to a safe location after labelling, the other transformer was still in service, but labelled and kept for replacement.

(Source: Details furnished by KSEBL)

Audit observed that:

- Though directions were received under Section 5 of the Environment Act, 1986 to dispose all the PCB based materials from the power utilities, KSEBL did not take any concrete action. The replacement of Clophen-filled transformers in the Idukki HEP proposed (2013) under the RMU was not carried out. Subsequently, replacement of the transformers was included (15 November 2017) under Power System Development Fund scheme and the same was pending (October 2019).
- Transformers filled with Clophen were hazardous to human beings and dangerous to handle in case of leakage. Further, no agency was available to attend to the rectification works of these transformers due to the hazardous nature.

[46] As per question answered (20 September 2007) in the European Parliament, since the end of 1977, Community legislation has banned the use of PCB, except for some closed systems such as electrical equipment transformers, for which PCBs were still allowed until 30 June 1986.

- In the aftermath of accidents in 2011 and 2013 in Idukki HEP, the Investigating Committee/ Vigilance Wing of KSEBL recommended replacement of all equipment which completed their life span. Five transformers commissioned in 1974-75 which exhausted their life span of 25 years were still in use, even after 43 years.
- The Sabarigiri HEP was having 14 transformers apart from the Clophen-filled transformers. The oil samples of two transformers randomly selected from these were sent to Central Power Research Institute (CPRI) for identifying the presence of PCB. Tests confirmed (November 2016) the presence of PCB in these two transformers also.

KSEBL replied (August 2020) that in Idukki HEP, the most critical factor for replacement of the Clophen filled auxiliary transformers was to keep the overall dimensions of new transformers within the dimensions of the existing transformers. However, budgetary quotation was being collected from reputed vendors in this regard. In respect of Sabarigiri HEP, the transformers were being replaced in a phased manner and in the case of Kuttiyadi HEP, both the transformers were decommissioned and were in the process of scrap disposal.

The reply was not acceptable. Though the replacement of Clophen-filled transformers was mandated by the Environment Act, 1986, KSEBL did not comply with this even after 33 years which was not justified.

Lack of insurance coverage

2.9.7.5 Business prudence requires that every business entity protects its critical assets and facilities from any damage or losses by insuring its assets. KSEBL, engaged in generation, transmission and distribution of power, owns and operates a number of electrical installations and facilities such as dams, power houses, penstocks, transmission and distribution lines *etc*. As on 31 March 2018, the book value of assets of the HEPs covered in audit worked out to ₹9.16 crore. Audit observed that:

- KSEBL mortgaged its assets, including the three HEPs examined in audit to the Life Insurance Corporation of India, as security for the loan availed in 1990. The assets, thus mortgaged, were insured with Kerala State Insurance Department against loss due to fire, flood, earthquake, typhoon, lightning, explosion, terrorism and other natural calamities. Since the loan was fully repaid (July 2018), KSEBL did not renew the insurance coverage thereafter. As such, the insurance coverage for the Idukki, Kuttiyadi and Sabarigiri HEPs expired in April 2018, October 2018 and November 2018 respectively.
- Due to the floods which occurred in 2019, generation from three (Units 4, 5 and 6) out of six units of Kuttiyadi HEP was suspended from 9 August 2019. The generation from Units 6, 5 and 4 was restored on 4 September 2019, 22 September 2019 and 1 November 2019 respectively. KSEBL incurred ₹5.00 crore for restoration of these units, but it could not recover the damage due to absence of any insurance cover for the Kuttiyadi HEP.

KSEBL replied (October 2020) that it would initiate steps to procure insurance coverage in consultation with KSERC.

Renovation, Modernisation and Uprating

2.10 Renovation, Modernisation and Uprating (RMU) of old HEPs is considered to be the best option to bridge the gap between demand and supply of power as RMU programmes are cost effective having much lower gestation period compared to setting up of new plants. RMU programmes are expected to be completed in about three to four years as against the installation period for new HEPs of six to seven years. Also, taking up RMU programmes timely prevents deterioration in the operation of HEPs. The Best Practices Guidelines issued by Central Electricity Authority (CEA) states that timely[47] RMU programme extends the operating life of HEP for another extended period of 20 to 25 years with improved reliability and availability. **Table 2.8** indicates the due date of RMU of HEPs covered in audit and the present status.

Table 2.8: Details of status of RMU programmes in HEPs

HEP and (Reservoir)	Installed capacity (MW)	No. of units and capacity (MW)	Year of commission	Due date of RMU	Present status
Idukki (Idukki)	Before RMU-390	I Stage-3x130	1976	2011	In progress
	After RMU-390				
	390	II Stage-3x130	1986	2021	-
Kuttiyadi (Kakkayam and Thariode)	225	KHEP-3x25	1972	2007	In progress
		KES-1x50	2001	2036	-
		KAES-2x50	2010	2046	-
Sabarigiri (Pampa and Kakki)	Before RMU-300	6x50	1966-67	2001-02	Completed in 2009
	After RMU-335	1 x 60 + 5 x 55			

[Source: Data from 'System Operations' prepared by Chief Engineer (System Operations), KSEBL]

Non-exploration of possibility of uprating

2.10.1 As per the Best Practices Guidelines of CEA, uprating of existing machines shall be taken up along with life extension programs, if feasible, by conducting prior uprating studies and it is possible to uprate the generating capacity of existing units by 10 to 30 *per cent* by undertaking uprating programmes[48].

[47] As per the Best Practices Guidelines for Renovation and Modernisation of Hydro Power Plants issued by Central Electricity Authority, the normative operative life of a hydroelectric plant is 30 to 35 years after which it requires life extension through RMU.

[48] This involve rewinding of stator from Class B to Class F, restoring stator core, improving air gap and replacing turbine runner with advanced blade profile and material.

As per para 2.5 of the Manual on Renovation, Modernisation, Uprating and Life Extension of Hydro Power Plants issued (February 2005) by Central Board of Irrigation and Power (CBIP), machines designed before and during the early eighties, were provided with Class 'B' insulation for stator and rotor windings[49]. With the development of Class 'F' insulation, the copper area of conductor in the existing slots can be increased by about 30 *per cent*. This would increase the capacity of the stator and rotor and with the existing margins in turbine, shaft and water conducting systems, the units can be uprated by 20 to 30 *per cent*. Audit observed that:

- KSEBL did not envisage to uprate the capacity of the three units of Idukki HEP for which RMU works were in progress though the uprating of capacity ranging from 6 to 20 *per cent* was part of all the recent RMU works carried out in HEPs such as Sabarigiri, Neriamangalam, Poringalkuthu, Pallivasal, Sengulam and Panniar. The non-exploration of uprating possibilities was not in line with the policy of KSEBL which aimed at optimal utilisation of hydro power resources to maximise the generation and to reduce power purchase. A 10 *per cent* increase in generation capacity of Idukki HEP Stage-I would have augmented its capacity by 39 MW.
- KSEBL replaced (2005-09) the stator winding and cooling system of Unit 6 of Sabarigiri HEP which resulted in the capacity enhancement of this unit by 10 MW. On the other hand, the stator winding in Units 1, 2, 3 and 5 were not replaced[50] instead the cooling system alone was replaced. As a result, the capacity enhancement of these units were limited to 5 MW. If the stator windings of Units 1, 2, 3 and 5 were also replaced, KSEBL could have further enhanced the generation capacity by 20 MW.

Failure to utilise the uprating potential of three units of Idukki HEP and of Units 1, 2, 3 and 5 of Sabarigiri HEP resulted in loss of generation capability of 212.04 MU *per annum*, which could have reduced the power procurement by KSEBL to that extent.

KSEBL replied (August 2020) that uprating of Idukki HEP units was not attempted as it required modification of water conducting and mechanical systems. There was also limitation for modifying the civil structures as the HEP was an underground power station. In the case of Sabarigiri HEP, for uprating the systems to get 30 *per cent* increase, the capacity of penstock and tunnel were to be increased. This would require long shutdown and to avoid it, the units were uprated to 10 *per cent* of its capacity.

The reply was not acceptable. KSEBL did not assess the feasibility of uprating the capacity of three units of Idukki HEP through Residual Life Assessment (RLA) studies. Hence, the limitation, if any, of the water conducting and other systems in

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[49] The generator is connected to the turbine drive shaft. It has a moving part–the rotor–and a fixed part–the stator. The rotor's outer surface is covered with electromagnets. The stator's inner surface, or cylinder wall, is made up of copper windings.

[50] In the case of Unit 4, the cooling system alone was replaced and the capacity was uprated from 50 to 55 MW. However, due to an accident in May 2008, Unit 4 was completely damaged and subsequently reconstructed with 60 MW in May 2014.

this regard was not established. In the case of Sabarigiri HEP, capacity of Unit 6 was uprated by 20 *per cent* without any modification in the water conducting system and as such capacity of other four units could have also been uprated by 20 *per cent* (instead of 10 *per cent*) if the windings were provided with Class F insulation. Further, as per CBIP, uprating of generating units by 20 to 30 *per cent* was possible using the new class of insulation for windings with the existing margins in turbine, shaft and water conducting systems.

RMU of Idukki HEP

2.10.2 Three units of Idukki HEP completed 35 years in 2011 and RMU was proposed (October 2012) under 12th Plan (2012-17). As a first step, a RLA study was conducted (August 2011) through CPRI. As per the Detailed Project Report (DPR) finalised in November 2013, the RMU was to be completed by July 2017 at a cost of ₹70 crore.

Residual Life Assessment study

2.10.2.1 As per para 7.6 of Best Practices Guidelines for Renovation and Modernisation of Hydro Power Plants of CEA, scope of RMU works and life extension programme in respect of generating units which have completed more than 30 years of service life should be firmed up based on RLA studies and the DPR prepared accordingly.

Audit observed that the RLA study recommended to maintain variation between maximum and minimum velocities of water flow within 10 *per cent* by improving the effectiveness of the ventilation system by providing new air guides, use of air baffles to direct the air flow and replacing the blades/ baffles[51] with improved design. But no specific proposal was included in the DPR to maintain the maximum and minimum water flow velocities within 10 *per cent* though the actual difference at the time of RLA study was 30 *per cent*. The non-adherence to the recommendations of RLA study was not in line with the Best Practices Guidelines issued by CEA.

KSEBL did not furnish any specific reply on the audit observation.

Tendering of RMU works

2.10.2.2 The RMU works was tendered (May 2014) with a probable amount of contract (PAC) of ₹42 crore. Two firms, Alstom India Private Limited (Alstom) and Andritz Hydro Private Limited (Andritz) participated and were prequalified (January 2015) and price bids were opened (March 2015). Though Andritz offered the lowest price (₹51.08 crore), the tender was subsequently cancelled (October 2015) as the Governor System[52] offered by the firm was not acceptable to KSEBL. The works were re-tendered (January 2016) and only Alstom submitted the bid.

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[51] Baffles are air flow ventilation channels used to direct the flow of air as part of cooling system of the generators.

[52] Governor System is the main controller of the hydraulic turbine. The governor varies the water flow through the turbine to control its speed or power output. Generating units' speed and system frequency are adjusted by the governor.

KSEBL accepted the bid (₹46.14 crore) and awarded (September 2016) the work with the time of completion of RMU works of all the three units by March 2020.

Audit observed that:

- The DPR provided five months for completing the tendering and awarding the work. KSEBL, however, took 26 months from issue of tender to final award of work. One of the reasons for the delay was defective technical evaluation of the bids as KSEBL failed to assess the suitability of the Governor System proposed by the bidders before prequalifying them. The unsuitability of the Governor System proposed by Andritz (lowest bidder) was noticed only after opening the price bid which led to cancellation of the tender.
- The DPR envisaged a period of 36 months from the date of award of work for completing the RMU works of all the three units. KSEBL provided a period of 42 months in the tender document and work order, which would have the impact of delaying the completion by another six months, in addition to the delay of 21 months occurred in the tendering stage.

The above deficiencies eventually postponed the benefit of RMU for a total period of 27 months compared to the period of completion envisaged in the DPR.

KSEBL replied (August 2020) that during prequalification, both the bidders offered Governor System as per tender specification. Andritz, however, changed their technical specification after opening of the financial bid. Hence, their offer was rejected and the work was retendered. As per the DPR, the time of completion of the RMU work was from July 2014 to December 2017 (43 months) and no additional time was given.

The reply was not acceptable. The Director (Supply Chain Management and Generation) instructed (November 2014) to assess the suitability of the Governor System proposed by Andritz for Idukki HEP even before the prequalification. The assessment was, however, carried out after opening the financial bid. The reply regarding time of completion of the work was factually incorrect as the DPR provided 36 months from July 2014 to July 2017 for completion of the work.

Execution of works

2.10.2.3 As per the DPR, RMU works of Unit 1 was to be completed first followed by Unit 2 and Unit 3, taking eight months each for completion. Similarly, as per the work schedule furnished by the contractor, RMU works of Unit 1 was to be completed by March 2018, Unit 2 by January 2019 and Unit 3 by July 2019. Audit observed that KSEBL handed over (June 2017) Unit 3 first to the contractor who took 18 months instead of 8 months and completed the RMU works only in December 2018. KSEBL handed over the second unit (Unit 2) in July 2019 and the RMU works were in progress (October 2020).

KSEBL stated (August 2020) that considering the maintenance history of generator shaft vibration, Unit 3 was handed over first. During execution of work, unforeseen events and extra works popped up which consumed time. Further, shut down of common systems were necessitated which could not be taken at the desired time as it was the major station in Kerala.

The reply was not tenable as the requirement of shut down of common systems was known to KSEBL and should have been considered in the planning stage itself. Further, non-availability of Unit 3 for an extended period of 10 months resulted in potential generation loss of 336.21 MU.

RMU of Sabarigiri HEP

2.10.3 Sabarigiri HEP was commissioned in 1966 with an installed capacity of 300 MW (50MW x 6 units). RMU works of the HEP were undertaken from 2005 to 2009 which enhanced the total installed capacity of the HEP to 335 MW (Units 1, 2, 3, 4 and 5 were uprated from 50 to 55 MW and Unit 6 from 50 to 60 MW).

Poor performance of Unit 4 after rebuilding

2.10.3.1 Unit 4 (55 MW) of Sabarigiri HEP was severely damaged in an explosion (16 May 2008), 15 months after completion (11 February 2007) of RMU works. KSEBL awarded (16 October 2009) the work of rebuilding Unit 4 (60 MW) to Puissance De L'eau Power Systems Pvt. Ltd. (PDL) for ₹52.20 crore. As against the scheduled completion of works by 15 November 2011, the Unit was completed and commissioned on 6 May 2014. As per the agreement, the contractor was liable to rectify all the defects noticed during the defect liability period of two years from the date of commissioning. Audit noticed that:

- The total generation from Unit 4 after rebuilding as compared to Unit 6 having similar installed capacity (60 MW) revealed that Unit 4 could not perform at the desired level as a result of repeated forced outages and technical problems. While Unit 6 generated a total of 1,257.61 MU of power during 2014-19, generation from Unit 4 was 609.40 MU of power (*i.e.* less than 50 *per cent* of Unit 6) during the same period.

- During the defect liability period (May 2014 to April 2016), several technical problems[53] were noticed which led to 49 instances of forced outage of the Unit for 1,366:49 hours. Out of the above, ten instances were for a duration exceeding 24 hours and the maximum duration of outage was up to 312 hours. The Unit experienced forced outages on a regular basis after the defect liability period also due to governor failures (366:56 hours), stator earth fault protection (4,795:35 hours) and vibration problems with continuous oil leak in turbine guide bearing (58:47 hours). As a result, KSEBL suffered generation loss of 201.60 MU of power and incurred additional expenditure of ₹59.07 crore towards purchase of power for supplementing this generation loss.

- In a meeting (November 2019) between KSEBL and the contractor, KSEBL stated that Unit 4 could not be loaded beyond 45 MW due to increase in vibrations and bearing temperature. Similarly, the windings which were

[53] Rotor earth fault, governor problems, oil leakage from nozzle, vibration in turbine guide bearing, SCADA rectification works *etc*.

expected to withstand 28 kV could not withstand even 12 kV. This indicated that the stator windings were vulnerable to failures.

- As per clause 19 of the terms and conditions of the purchase order, the weighted average efficiency of the turbines shall not be less than 90.82 *per cent*. If the shortfall is 2.00 *per cent* or more, the turbine will be rejected. As per CEA Regulations 2010-Technical Standards for Construction of Hydro-Electric Generating Stations, the weighted average efficiency of the turbine should be determined after the installation and commissioning of the generating units on the basis of field acceptance test. KSEBL did not, however, specify any timeframe for conducting the field efficiency test at least before the expiry of defect liability period (by April 2016). The field efficiency test of the turbines conducted by CPRI in July 2018 revealed that the turbine efficiency ranged between 83.74 *per cent* and 84.85 *per cent*. As the field efficiency test of the turbines was conducted after a lapse of two years from the expiry of defect liability period, it proved a futile exercise. Meanwhile, KSEBL issued (August 2020) a notice to the contractor seeking explanation as to why the turbine should not be rejected on account of the shortfall in turbine efficiency.

From the above, it is evident that Unit 4 failed to perform in accordance with the parameters guaranteed by the contractor. But, KSEBL did not enforce the applicable contract conditions for making good the loss suffered by it in terms of generation loss.

KSEBL replied (August 2020) that the breakdowns in the generating unit could be explained based on the life cycle curve called the bath tub curve[54] which has three phases, *viz*., break-in-phase/ infant mortality phase, second phase/ optimum level and the last/ final phase. An amount of ₹2.58 crore was available with KSEBL towards security deposit and any recoveries, if needed, could be made from this.

The reply was not acceptable. As per the bath tub curve, while a generating unit in the infant mortality phase was expected to show a declining trend of failures, Unit 4 showed an increasing or persisting trend of failures since its commissioning, rendering ₹52.20 crore spent for reconstruction of Unit 4 infructuous in addition to the extra expenditure of ₹59.07 crore for procuring power during 2014-19. In view of continuous vibration problems, KSEBL decided (July 2020) to shut down the operation of the unit for ensuring safety. Specific reasons as to why the problems and the associated forced outages occurred from the defect liability period till date were not stated in the reply. The reply was also silent regarding the vulnerability of the stator windings and the non-compliance of CEA Regulations on the conduct of timely field efficiency test.

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[54] The bathtub curve is widely used in reliability engineering. It describes a particular form of the hazard function which comprises three parts: the first part is a decreasing failure rate, known as early failures, the second part is a constant failure rate, known as random failures, the third part is an increasing failure rate, known as wear-out failures.

RMU of Kuttiyadi HEP

2.10.4 Kuttiyadi HEP having a capacity of 3x25 MW was commissioned in 1972 and has completed 47 years of service. KSEBL entrusted (March 2012) Alternate Hydro Energy Centre (AHEC) of IIT Roorkee to conduct the Residual Life Assessment (RLA) study of the HEP and the RLA study report was submitted in June 2014. KSEBL accorded (June 2017) administrative sanction for ₹327.20 crore for the RMU work based on a DPR (May 2017) envisaging 38 months for its completion. KSEBL tendered (December 2017) the electro-mechanical works, but the tender was cancelled (July 2018) due to lack of competition. The works were re-tendered in November 2018 and awarded in September 2019 to BHEL at ₹89.82 crore.

Audit observed that:

- As per the Best Practices Guidelines on Renovation and Modernisation of Hydro Power Plants by CEA, the normative operative life of HEP was 30 to 35 years after which it required life extension through renovation. Though the RMU of Kuttiyadi HEP was due in 2007, implementation of RMU works commenced with the award of electro-mechanical works in September 2019 only, after a delay of 12 years.

- When the HEP was about to complete 30 years of operative life, a feasibility study on RMU was conducted by the Japan Bank for International Cooperation through Electric Power Development Company Ltd. (Japan) during 2001-02. Even though the feasibility study recommended replacement of major equipment, KSEBL did not initiate any action for the next 10 years.

- As per the Best Practices Guidelines on Renovation and Modernisation of Hydro Power Plants by CEA, RLA studies are conducted to get a realistic picture regarding the residual life/ condition of the entire equipment, systems and sub systems[55] in the HEP. KSEBL did not include the equipment proposed for replacement/ renovation in the RMU feasibility study conducted during 2001-02 in the scope of RLA study through AHEC and confined the study to the combined water conducting system of the HEP, the existing penstock and turbine header.

- KSEBL appointed (August 2014) a technical sub-committee for preparation of the DPR directing it to submit the DPR by first week of September 2014. The DPR was, however, finalised only in May 2017. KSEBL took 35 months to finalise the DPR due to lack of coordination between various functional wings involved in its preparation.

[55] Category I: Hydro turbines, generators, valves, governors, excitation, system equipment and station auxiliaries.
Category II: Main power transformers and switchyard equipment.
Category III: Hydro mechanical equipment like gates, trash rack, stop logs and gate operating mechanisms.
Category IV: Civil engineering elements/ components namely dams, intake, water conductor system, power house building, foundations *etc*.

As the RLA study recommended (June 2014) uprating of the capacity of generating units by 10 *per cent*, the benefits from the additional generating capacity of 7.5 MW (*i.e.*, 2.68 MU of power *per annum*) could not be realised. Thus, the possibility of improved machine availability and optimum use of water by undertaking RMU work did not materialise.

KSEBL replied (August 2020) that though the machines were old and needed replacement, there was no threat to the availability of the machines.

The reply was not tenable as it was silent on why KSEBL took 12 years to initiate the RMU works.

Recommendation 2.4*: *Priority may be accorded for developing and implementing a detailed system and procedures for periodical maintenance and upkeep of equipment at HEPs. The implementation of the system may also be monitored at senior management level.

Recommendation 2.5: Clear and rational policy and procedures may be evolved in accordance with the guidelines issued by Government/ Central Electricity Authority for timely renovation, modernisation and uprating of HEPs so that the benefits from RMU are maximised.

Conclusion

The generation capability of the HEPs was not optimally utilised leading to generation loss of 496.92 MU of power and additional expenditure of ₹145.59 crore. There were deficiencies in planning and execution of renovation, modernisation and uprating of HEPs. Failure to utilise the uprating potential resulted in loss of generation capability of 201.60 MU of power *per annum.* There was avoidable delay in finalising and implementing RMU of Idukki and Kuttiyadi HEPs. A rebuilt generating unit of Sabarigiri HEP failed to perform at expected levels due to technical issues resulting in generation loss of ₹59.07 crore. The HEPs did not achieve the norm of 90 *per cent* Plant Availability Factor due to forced outages as a result of inefficient maintenance. As a result, KSEBL could not generate 920.71 MU of power causing extra expenditure of ₹269.77 crore.