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SMALL HYDROPOWER PROJECT: STANDARD PRACTICES

Priyabrata Adhikary[1], Susmita Kundu[2]

[1]*Assistant Professor (Mechanical), S.V.I.S.T. (W.B.U.T.), Kolkata, India* ***priyabrata24@gmail.com***
[2]*Assistant Professor (Electrical), M.S.I.T. (W.B.U.T.), Kolkata, India* ***susmita_kundu7@rediffmail.com***

Abstract

Small hydropower projects (SHP) are emerging as a solution for sustainable, green, environment friendly and long term, cost-effective source of renewable energy in India for the future. Selecting the appropriate small hydropower project and its parameters such as project development, plant operation, plant maintenance etc. in which to invest is a critical task involving different factors and policies. In this paper an attempt is made to discuss types of small hydropower schemes and present a methodology on development, operation and maintenance of small hydropower projects. To the best of the author's knowledge this novel approach for standard practice on small hydropower project development, operation, maintenance scenario is absent in renewable energy literatures due to its assessment complexity.

Index Terms: *Small Hydropower Development, Plant Operation, Plant Maintenance, Renewable Energy, MCDA*

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1. INTRODUCTION

In India, the total installed power generating capacity was reported as 2, 02,979.03 MW (2012) out of which only 19.24% i.e. 39,060.40 MW is thru hydro power. The identified small hydropower project (SHP) potential sites are 14300 MW (approx) and installed are 2150 MW (approx.) [1, 2]. The cost of clean-green-friendly small hydroelectricity is relatively low i.e. Rs2.5/KWH (approx.), compared to others and thus making it a competitive source of renewable energy as demonstrated. It is much more advantageous over conventional large or medium hydropower projects. Some industries, like oil refining, health care and power generation have (24x7) type continuous schedules almost from the day they start [3, 4]. When a company needs to move from 5-day operations to 7-day operations, the strategy can result in significant human relations and operational problems if not handled properly and needs critical decision makings. Setting up a power plant is complex, time consuming, too long completion time, with large number of uncertainties [5, 6]. Therefore, an understanding of a decision making process, its involvement, its criticality, and some effective techniques as MCDA or MCDM tools, may become helpful to produce better understanding and results. The common factors that affect decision making of a sustainable solution are technical, economic, environment and social [7, 8].

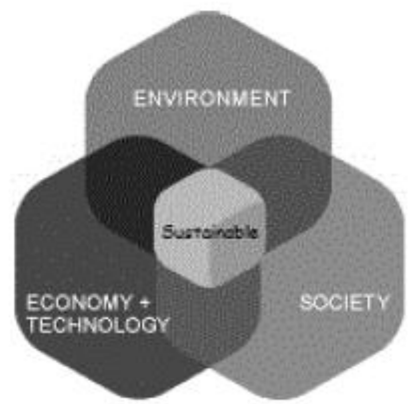

Fig-1: Sustainable Renewable Energy Solution - SHP

Small hydropower projects (i.e. up to 25MW in India) are much more advantageous than conventional medium or large hydropower projects. Small hydropower plant requires very less flow or head compared to conventional hydropower plants. Reservoir is also not required for small hydropower projects as they are mostly run-of-river type. Environmental and social impacts of small hydropower projects are also negligible compared to conventional medium or large hydropower projects [9, 10].

Small hydropower project schemes are classified as mentioned below:

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 # Run-of-river scheme: They utilize the instantaneous river flow without a dam. A weir or a barrage is constructed across the river simply to raise the water level slightly and divert water into a conductor system for power generation. Such a scheme is adopted in the case of a perennial river.

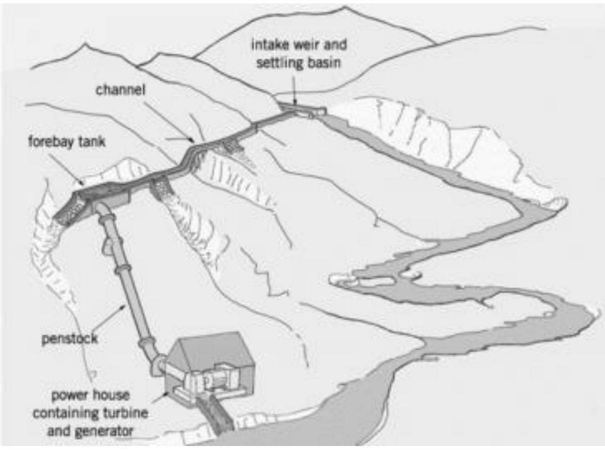

Fig-2: Run of River Based - SHP

 # Canal fall based scheme: These schemes are planned to generate power by utilizing the flow and fall in the canal. These schemes may be planned in the canal itself or in the by-pass channel. These are low head and high discharge schemes. These schemes are advantageous due to low gestation period, simple layout, no rehabilitation problems and no socio-environmental problems.

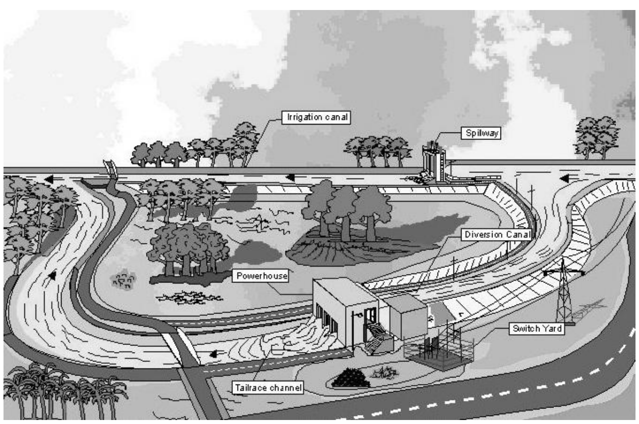

Fig-3: Canal Fall Based - SHP

 # Dam-Toe scheme: Here the head is created by raising the water level behind the dam by storing natural flow and the powerhouse is placed at the toe of the dam or along the axis of the dam on either side. The water is carried to the powerhouse through a penstock.

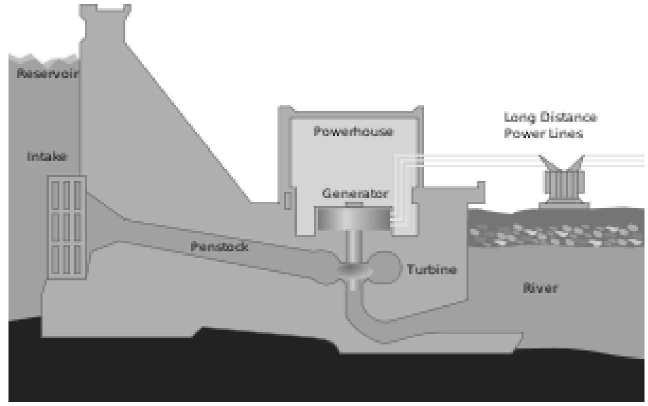

Fig-4: Dam Toe Based - SHP

 # Pumped storage scheme: It is a method of keeping water in reserve for peak period power demands by pumping water that has already flowed through the turbines back up a storage pool above the power plant at a time when customer demand or tariff for energy is low, such as during the middle of the night. The water is then allowed to flow back through the turbine-generators at times when demand is high and a heavy load is placed on the system. Because pumped storage reservoirs are relatively small, construction costs are generally low compared with conventional hydropower facilities.

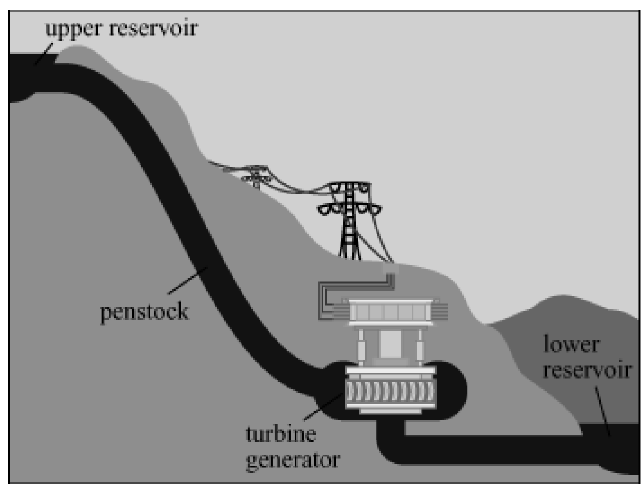

Fig-5: Pumped Storage Based - SHP

There are two basic components in all four types of SHP schemes; i.e., civil works (Diversion and intake, De-silting tank, Power channel, Fore-bay, Penstock, Powerhouse building, Tail race channel etc.) and electro-mechanical equipment (Valves, Hydraulic Turbine, Generator etc.). Most of the components are same in different types of schemes;

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some components, however, are different. The development of small hydro projects typically takes from 2 to 5 years to complete, from conception to final commissioning. This time is required to undertake studies and design work, to receive the necessary approvals and to construct the project. It can be operated by trained full time or even part-time operator. Trained personnel are required for plant maintenance. Once constructed, small hydro plants require little maintenance over their useful life, which can be well over 35 to 50 years [11, 12].

2. PLANNING & DEVELOPMENT (SHP)

Small hydropower project development involves following stages as mentioned below:

Reconnaissance survey and Pre-feasibility Analysis: A quick and inexpensive initial examination, the pre-feasibility analysis determines whether the proposed project has a good chance of satisfying the proponent's requirements for profitability or cost-effectiveness, and therefore merits the more serious investment of time and resources required by a feasibility analysis. It is characterized by the use of readily available site and resource data, coarse cost estimates, and simple calculations and judgements along with a site visit. These can be done physically or by software (RETScreen, IMP5.0 etc.).

Feasibility Analysis: A more in-depth analysis of the project's prospects, the feasibility study must provide information about the physical characteristics, financial viability, and environmental, socio-economic, or other impacts of the project, such that the proponent can come to a decision about whether or not to proceed with the project. It is characterized by the collection of refined site, resource, and equipment data. It typically involves site visits, resource monitoring, energy audits, more detailed computer simulation, and the solicitation of price information from equipment suppliers or contractors.

Engineering and Development: Engineering includes the design and planning of the physical aspects of the project. Development involves the planning, arrangement, and negotiation of technical and financial, regulatory, contractual and other non-physical aspects of the project. This work would include the final design of the plant and transmission system; integration of the transmission system; integration of the project into the power network to determine precise operating mode; production of techno – commercial tender with drawings and specifications.

Construction and Commissioning: Finally, the project is built and put into service. Certain construction activities can be started before completion of engineering and development, and the two conducted in parallel. It includes site supervision or project management.

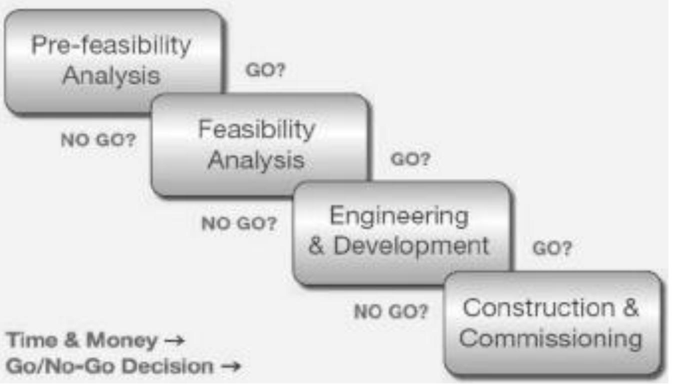

Fig-6: Project Implementation Stages - SHP

3. OPERATION (SHP)

Again Small Hydropower Plant operation can be divided under four verticals as mentioned below:

Operation Management: It includes: taking over of SHP plant after commissioning; develop & maintain proper plant operation manual and reports – daily, weekly, monthly, yearly; skilled manpower shift scheduling; regularly training the manpower on plant & connected power systems etc. It may involve maintaining - daily (Meter reading log book, Pump running report etc.), weekly (Relay tripping report, pending fault report, accident report etc.), monthly (training report, generation report, outage report etc.) and yearly (generation report, generation loss report, outage report, maintenance report etc.) reports.

Water Management: It includes: knowledge or database of river hydrology; diversion of water for electricity generation; plugging loss of water in water conductor system etc.

Maintenance Management: It includes: database of all plant components; availability of required drawings, records, documents, spares, consumables; plant performance records etc.

Personnel Management: It includes: man power planning for operation and maintenance; shift scheduling; staff facilities management and training; plant outage and grid authority co-ordination etc.

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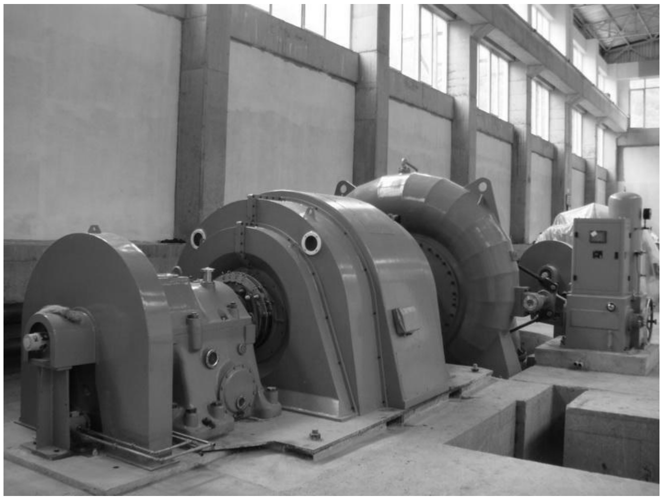

Fig-7: Small Hydropower Project under operation

4. MAINTENANCE (SHP)

The small hydropower plant components are constantly stressed by a number of factors which affect the life of the individual components and of the power house. The usefulness of the equipment can be substantially increased by carrying out the proper operation by trained manpower and maintenance of the machine or parts by skilled manpower and by taking such maintenance steps many faults can be prevented. The plant maintenance ensures: reliable and uninterrupted power supply; full utilization of existing plant and machines; reduced O & M cost; reduced - outages, breakdown and better efficiency; increased durability. Maintenance of power plant includes: daily check schedules, weekly check schedules, monthly check schedules, half yearly check schedules, annual check schedule and overhauling.

Maintenance of electrical systems include: generator, transformers, switch yard equipment, station auxiliaries, excitation system, controls, metering, protection systems etc. Maintenance of hydro-mechanical components includes turbine, barrage gates, head regulator gates, intake gates, spillway gates, trash racks, MIV, expansion joints etc. Maintenance of civil structures includes barrage, head regulator, de-silting basin, power channel or tunnel, fore bay, surge tank, tail race channel, power house building, switch yard foundations and trenches etc. Hence updated daily report, weekly report, monthly report, half yearly or annual report plays a crucial role.

Small Hydropower Plant maintenance are of four types as mentioned below:

Breakdown maintenance: This is done after operating the machine till it fails which should not be accepted by any management but in small hydro power stations it is very common.

Routine maintenance: In this category, the machines are maintained at suitable intervals by inspection, cleaning, tightening of nuts and bolts and repairing different components without completely dismantling the machines. It may involve - daily, weekly, monthly, quarterly, biannually or annual routines.

Fig-8: Small Hydropower Project under maintenance

Preventative maintenance: In this type of maintenance different diagnostic test on different parts of the machine are carried out to ascertain the condition and health of the equipment. On the basis of these tests, the residual life of different parts can be assessed. Parts needing immediate or near future replacement can also be identified. Thus the preventive maintenance enables us to predict the potential faults which occur in future and enable us to make remedial steps to prevent these potential faults.

Capital maintenance: During any routine maintenance, the machine is not dismantled and so the major portion of most of the components like stator windings, rotor windings, guide vanes etc. remains inaccessible. It is not even possible to inspect these parts properly. The extent of deterioration is not known. It is therefore necessary that the machine be completely dismantled so that all the parts are properly inspected and whenever required necessary repair is carried

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out. The periodicity of capital maintenance depends upon plant to plant.

5. DICISSION MAKING (SHP)

Small hydropower projects are complex, interdisciplinary integrated systems, because there are large numbers of civil, mechanical and electrical components with different characteristics. The success of a small hydropower project is no longer dominated by only economic criteria. Several other criteria, such as environmental, social and technical aspects need to be taken into consideration. Therefore, small hydropower project development can be analyzed as a typical multi-criteria decision analysis problem. Inaccurate design, improper selection of project or any parameter will have high negative impact on the overall cost and efficiency. Thus it will result in producing less power at a higher cost-per-watt. In general, evaluating or decision making of small hydropower project or any of its parameter is a complex analysis. The use of multi-criteria decision analysis (MCDA) or multi-criteria decision making (MCDM) or multi-criteria analysis (MCA) techniques can provide a reliable methodology to rank alternatives in the presence of different objectives and limitations [1, 2]. These methods can be used as empirical validation and testing tools of various needs. In addition they can be also applied to group decision making scenario as well as for uncertainty analysis. A review of various published literatures on sustainable energy planning indicates greater applicability of MCDA methods in changed socio-economic scenario [3, 4]. The methods have been very widely used to take care of multiple, conflicting criteria to arrive at better solutions. Increasing popularity and applicability of these methods beyond 1990 indicate a paradigm shift in renewable energy planning, development and policy analysis. More research is still to be done to explore the applicability and potentiality of more MCDA methods to real-world planning and designing problems to reduce the gap between theory and practice. Many soft-wares (1000Minds, D-Sight etc.) have also been developed to facilitate such analysis or study [5, 6]. The preliminary step in MCDA method is to formulate the alternatives for sustainable energy decision making problem from a set of selected criteria (technical, economical, environmental, social etc.) and to normalize the original data of criteria. The purpose of normalization is to obtain dimensionless values of different criteria so that all of them can be compared. Secondly, criteria weights are determined to show the relative importance of criteria in MCDA method. Then, the acceptable alternatives are ranked by MCDA method with criteria weights. Finally, the alternatives' ranking is ordered. If all alternative rank orders, in different MCDA methods are just the same, the decision making process is ended [7, 8]. Otherwise, the ranking results are aggregated again and the best scheme is selected. Popular criterion selection methods are Delphi Method, Least Mean Square (LMS) Method etc. All criteria or factors have their internal impact reclassified to a common scale. Weight is assigned to the criteria to indicate its relative importance. Different weights influence directly the results or ranking [9, 10]. Consequently, it is necessary to obtain the rationality and veracity of criteria weights. Three factors are usually considered to obtain the weights: the variance degree of criteria, the independency of criteria and the subjective preference of the decision-makers. Popular weighting methods are Equal Weights Methods, Subjective Weighting Methods (Delphi Method, AHP etc.), Objective Weighting Methods (LMS Method, TOPSIS etc.) and Combined Weighting Methods. Then it is the turn to determine the preference orders of alternative after determining the criteria weights so that MCDA or MCDM Methods are employed to get the ranking order. For water resource or renewable energy projects MCDA or MCDM methods are divided into four categories: Distance Based Method (TOPSIS, VIKOR etc.), Outranking Method (ELECTRE, PROMETHEE etc.), Priority or Utility Based Method (Weighted Average Method, AHP etc.) and Mixed Category (EXPROM-2, STOPROM-2 etc.). Usually, the decision maker selects the best alternative based on the ranking orders after the calculation in a selected MCDA method. However, the creditability of a process is necessarily verified so that the results of the ranking orders are computed by a few other MCDA methods sometimes along with a final physical verification [11, 12]. The application of various MCDA methods of calculation may yield different results. Therefore, the ranking results are necessarily aggregated again and the best scheme from the alternatives is selected. The methods used to aggregate the preference orders are called as aggregation methods (Voting Method, Mathematical Aggregation Method etc.).

6. DISCUSSION

There is a series of standards, guidelines and manuals on hydropower development issued by international standards organizations like ISO, IEC, IEEE, ASME, USBR and the national statuary bodies of several countries, including India (CEA, REC, BIS and CBIP). But most of them were prepared keeping in view the large or medium hydropower projects. To make SHP cost effective and reliable, standard guidelines are required covering entire range of SHP (Pico, Micro, Mini and Small) activities. Necessity of the standard guidelines has been strongly felt by developers, manufactures, consultants, regulators and others. The efforts of MNRE, Government of India have taken initiatives to prepare the same for SHP and are expected available shortly for entire range of SHPs.

7. CONCLUSION

The rural energy scenario in India is characterized by inadequate, poor and unreliable supply of energy services. Realizing the fact that small hydropower projects can provide a solution for the energy problem in rural, remote and hilly areas where extension of grid system is comparatively uneconomical. Necessity of the standard guidelines on SHP has been strongly felt by developers, manufactures, consultants, regulators and others. A number of small (pico, mini, micro or small) hydro projects have been set up in remote and isolated areas, mainly in Himalayan region. While these projects are developed by various state agencies responsible for renewable energy, the projects are normally maintained with local community participation. Isolated grid often faces the problem of poor plant load factor and making financial return difficult for the plant. But this provides opportunities for the overall socio-economic development of the area and hence gaining importance.

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REFERENCES

[1] Adhikary,P., Roy,P.K., and Mazumdar,A.: Safe and efficient control of hydro power plant by fuzzy logic, IJESAT, Vol.2, Issue-5, pp. 1270-1277 (2012)

[2] Adhikary,P., Roy,P.K., and Mazumdar,A.: MCDA of manpower shift scheduling for cost effective hydro power generation, IJETED, Vol.7, Issue-2, pp. 116-127 (2012)

[3] Adhikary,P., Roy,P.K., and Mazumdar,A.: Selection of Penstock material for small hydropower project – A Fuzzy Logic Approach, IJAST-TM, Vol.6, Issue-2, pp. 521-528 (2012)

[4] Adhikary,P., Roy,P.K., and Mazumdar,A.: Selection of hydro-turbine blade material – Application of Fuzzy Logic (MCDA), IJERA, Vol.3, Issue-1, pp. 426-430 (2013)

[5] Adhikary,P., Roy,P.K., and Mazumdar,A.: Fuzzy Logic based user friendly Pico-Hydro Power generation for decentralized rural electrification, IJETT, Vol.4, Issue-4, pp. 507-511 (2013)

[6] Adhikary,P., Roy,P.K., and Mazumdar,A.: Fuzzy logic based blade angle control of Kaplan turbine for a hydro power project, ICERTSD 2013 (BESUS), Paper No: ICERTSD-13-109 (2013)

[7] Adhikary,P., Roy,P.K., and Mazumdar,A.: Hydraulic transient analysis of SMALL HYDROPOWER PROJECT: A MCDM application for optimum penstock design, IWMSID 2013 (IIT-Bhubaneswar), Paper No: IWMSID / WRE / 16 (2013)

[8] Adhikary,P., Roy,P.K., and Mazumdar,A.: Indian small hydropower Project Planning And Development : A Review Of DSS Tools, IJERT, Vol.2, Issue-6, pp. 1386-1391 (2013)

[9] Adhikary,P., Roy,P.K., and Mazumdar,A.: Fuzzy Logic based optimum penstock design: Elastic Water column theory approach, ARPN-JEAS, Vol.8, Issue-7, pp. 563-568 (2013)

[10] Adhikary,P., Roy,P.K., and Mazumdar,A.: Optimum selection of Hydraulic Turbine Manufacturer for SHP:MCDA or MCDM Tools, IDOSI-WASJ, Vol.28, Issue-7, pp. 914-919 (2013)

[11] Adhikary,P., Roy,P.K., and Mazumdar,A.: Multi-dimensional feasibility analysis of small hydropower project in India: a case study, ARPN-JEAS, Vol.9, Issue-1, (2014)

[12] Adhikary,P., Kundu,S.: MCDA or MCDM based selection of transmission line conductor: Small hydropower project planning and development, IJERA, Vol.4, Issue-2, pp. 357-361 (2014)

BIOGRAPHIES

Priyabrata Adhikary is presently working as an Assistant Professor-Mechanical at S.V.I.S.T. (W.B.U.T.), Kolkata for last 2-years. Prior to teaching he is also having 8-years of H.V.A.C. & R industry experiences in India and abroad (GCC). He has done his B.E. (Mechanical) and M.E. from Jadavpur University. He is author for several national and international publications.

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Susmita Kundu is presently working as an Assistant Professor-Electrical at M.S.I.T. (W.B.U.T.), Kolkata for last 10-years. She has completed her B.Tech (EEE) from S.M.I.T. and M.Tech from Calcutta University. She is author for several national and international publications.