An Innovative Approach for Generating 1 MW of Electricity through Setting up of Micro Hydel Power Plants at Hub Dam, Karachi, Pakistan

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Abstract: Energy crisis in Pakistan is getting worst and worst with the passage of time due to the increasing gap between the supply and demand of electricity. One of the main reasons of this crisis is that in Pakistan maximum power plants are either hydel or thermal based. The recent increase in oil prices globally makes it difficult to provide cheaper electricity through thermal or furnace based power plants. Similarly setting up of new hydel power plants or maintaining the existing ones is an expensive affair. Keeping these factors in front it is the right time to find out viable alternate solution of power generation so that power crises in the country can be tackled. Pakistan is blessed with ample water resources throughout the year but unfortunately more than 50% of this water is being wasted because of non-availability of proper storage facilities. In order to seek low cost solution to power generation these water resources can be utilized easily through the setting up of micro hydel power plants in the flow of water at appropriate location with reasonable water head. These micro hydel power plants are comparatively cheaper and easy to establish without disturbing the actual flow of water. Presently many types of Micro Hydel Power Plants are available in the world which are very efficient and can be set up easily without disturbing the flow of water if reasonable water heads are available. In order to combat ongoing energy crises a detail survey / analysis of hub dam and its canals were carried out. The dam is situated 45 KM from Karachi city with a water storage capacity of 857000 Acre ft and supply water to Karachi, Lasbella and Hub cities on daily basis. The analysis suggest that different MHPPs can be set up at suitable locations of Hub Dam and in the way of canal flowing from the dam where ever a head of 3 to 7 m and a flow of 200 to 300 CUSEC is available. The expected power generation through this work is approximately 1 MW which can be directly delivered to the national grid without affecting the basic flow of water.

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Introduction

MHPPs are the best and easy option for generating electricity locally if proper flow of water with appropriate head is available. Many countries which are blessed with good water resources have set up MHPPs for electricity generation without disturbing the flow line of water. The hub dam located near Karachi, Pakistan is basically a storage dam which supplies water to metropolitan city of Karachi, Lasbella and Hub on daily basis. The detail analysis / survey reveals that the location and canals systems of this dam is best suited for the establishment of MHPPs at appropriate position wherever 3 to 7 meter of water head is available [1, 2].

The hub dam is situated about 40 KMs North of Karachi city on provincial boarder of Sindh and Balochistan provinces of Pakistan with an estimated water storage capacity of 857000 acre feet. It is the third largest dam of Pakistan having an area of 24300 acres while the height of the dam is 97.5 meters / 320 ft (figure 1 & 2). There are three main canals emerging from the reservoir which are providing water to Karachi, Hub and Lasbella cities [3]. The preliminary work of Hub Dam was started in 1963 and completed in 1981 with a capital cost of Rs 843.597 million. It is designed to supply 100 MGD and 25 MGD to Karachi and Hub cities respectively besides 44 MGD and 2 MGD for irrigation purpose to different areas of Baluchistan and Sindh respectively [3, 4]. This large amount of water flowing from the dam to different canals with multiple water heads available during the flow make it suitable for setting up of MHPPs.

The dam

Figure 3 and 4 show dam water reservoir aerial view while table-1 lists salient features of dam [3, 5, 6, 7]. Figure 5 shows a sketch of proposed locations of MHPPs at different points on dam and canals emerging from dam.

Figure 1: Water Height of the Hub Dam

Figure 2: The Hub Dam Storage

Figure 3: Aerial View of the Hub Dam

Figure 4: Aerial View of the Hub Dam

Table 1: Hub Dam salient features [3, 5, 6, 7]

General Purpose	Storage/supplying of water to Karachi, Hub and Lasbella
Year of Start	1963
Completion	1981
Total Cost	Rs 843.597 Million
Life of Dam	75 years
Type of Dam	Earthen
Location	45 KM North-East of Karachi , Sindh, Pakistan
Area	24300 Acres, Catchment : 3410 square miles
Dam Height	97.5 meters / 320 ft
Dimension of Dam	Height / Length / Width 350 / 15640 / 965 ft
Storage Capacity	857000 Acre Ft (1057000,000 m^3)
Spill Way	Ungated, Manually controlled, Crest Length:6020 ft Elevation : 339.3 ft, Max outflow : 458000 CUSIC
Flood (Maximum)	Anticipated : 480000 CUSIC, Recorded : 521000 CUSIC
Reservoir Level	Full / Max reservoir level : 350 ft / 365 ft
Release	216406 Acre ft

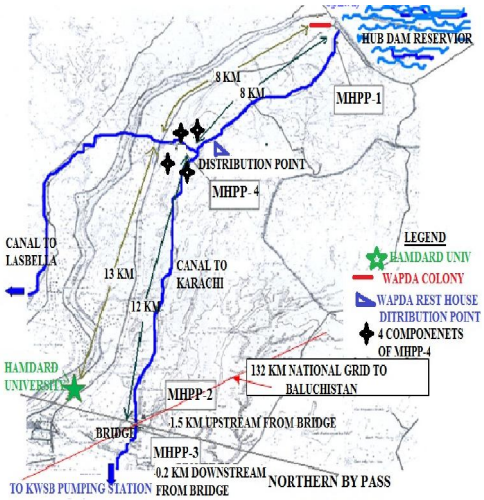

Figure 5: MHPPs proposed locations during the flow of water with approximate distances

The Canal System

The canals system of hub dam consists of one main canal being controlled through Karachi Water and Sewerage Board pumping station which fulfill the water requirements of metropolitan city of Karachi with a designed discharged capacity of 370 CUSEC/10.48 CUMEC as shown in figure 6. This canal is bifurcated into two main branches after flowing 8.32 KM at head regulator from where water supply to Karachi and Lasbella are controlled as shown in figure 7 and figure 8 while figure 9 shows manually operated vertical gates to control the flow of water.

Figure 6: Main Canal Flow from Hub Dam

Figure 7: Bifurcation to Karachi and Lasbella through Manually Operated Gates

Figure 8: Bifurcation to Karachi and Lasbella through Manual Gates

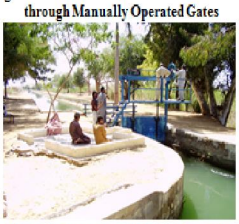

Figure 9: Operating of Manual Gates from Controlling Water Supply

Water storage and flow from Hub Dam

Figure 10 shows annual inflow / release of water from the Dam for 31 years (1979 to 2009) while figure 11 shows 30 years hub dam release / spill data with an average inflow and release of water from the dam for last five years to be 271815 Acre ft and 928351 Acre ft respectively [8].

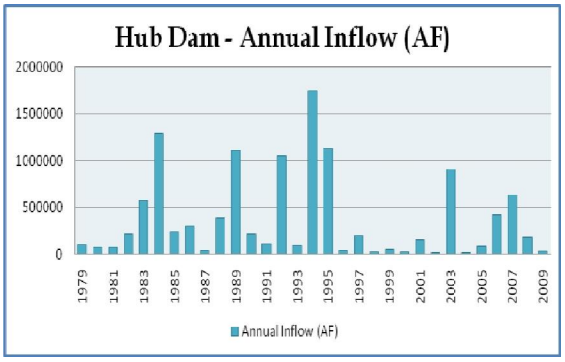

Figure 10: Annual inflow in Hub Dam (1979-2009)

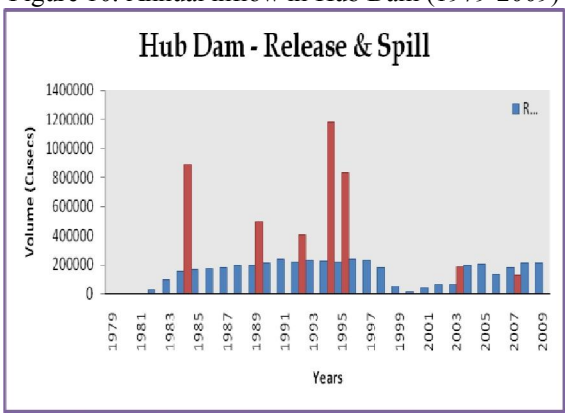

Figure 11: Annual release from Hub Dam (1979-2009)

Proposed sites for the setting up of MHPPs

As water releases from the dam to the main canal having a flow of 370 CUSEC, a suitable head is seen which is appropriate for the installation of MHPP-1 as shown in figure 12 and figure 13. This main canal is a 22.4 KM long open channel canal terminating at main pumping station of Karachi Water and Sewerage Board. It is lined with concrete tiles and crosses a number of natural drainage channels and a main road bridge besides 3 small bridges on village road. The thorough analysis showed that this flow has two water fall structures where two MHPPs (MHPP-2 & MHPP-3) can be setup as shown in figure 14 and 15 without interrupting the supply of 100 MGD of water. Similarly Lasbella canal branch is 33.6 KM long with a design discharge capacity of 160 CUSEC supplying 60 MGD water for drinking, irrigation and industrial purposes to Lasbella city. This canal is also a lined canal comprises of 8 minor channels for irrigation purposes besides many outlets for industrial water supply thus suitable for setting up of two MHPPs. Moreover, Band Murad Minor, from where water is being supplied on replacement basis to 1000 acres of agricultural farms can also be suitable for setting up of MHPP. The point from where water is distributed to Lasbella city through Lasbella canal (33.6 KM long with 160 CUSEC capacity) can be one of the location for installation of MHPP-4 in four parts as there are four heads of approximately 3 meters each are available [9, 10].

Figure 12: Water from Hub Dam to Main Canal Proposed Site for MHPP-1

Figure 13: 370 CUSEC Water from Hub Dam to Main Canal Proposed Site for MHPP-1

Figure 14: 170 CUSEC Water from Hub Dam to Main Canal Proposed Site for MHPP-2

Figure 15: 150 CUSEC Water from Hub Dam to Main Canal Proposed Site for MHPP-3

Expected power generation

The estimated electricity to be produce based on water flow and availability of appropriate heads is about 1 MW. The detail of electricity produced at different proposed sites through MHPPs along the flow of water/heads available is given in table-2 [11, 12].

Table 2: Total estimated energy generated

Site / MHPPs	Flow in CUSEC	Flow in CUMEC	Head (H) in Meters	Plant Efficiency (η)	P=9.81* Q*H* η (In KW)
MHPP-1	370	10.48	7	0.7	503.76
MHPP-2	210	5.95	3	0.7	122.57
MHPP-3	210	5.95	3	0.7	122.57
MHPP (2 +3)			7.62	0.7	311.34
MHPP-4	160	4.53	2.18 (A) 2.2 (B) 1.5 (C) 1.3 (D)	0.7	67.81 68.43 - -
MHPP (A+B+C+D)			7.18	0.7	223.35
Total power					**1038.45**

Technical proposals and cost analysis of all sites

Micro Hydel Power Plant-1 (MHPP-1)

MHPP- 1 is proposed to be setup just at the opening of water flow from the dam/reservoir where a suitable head of 7 m is available as shown in figure 12 earlier. Due to a 7 meter head availability, Kaplan turbine is best to be installed here with an adequate penstock as shown in figure 16 (Kaplan turbine is best for heads between 2-8 Meters for maximum power capacity up to 2.6 MW) [13, 14] while figure 17 shows inside view of Kaplan turbine installed as MHPP-1. Table 3 enlists generator components requirements for MHPP-1 [14]. It is pertinent to mention here that water head may rise as the water coming from nearby catchment areas and regular rain in the area thus providing excellent working head for Kaplan turbine.

Table 3: Generator Specification MHPP-1 [14]

Type	Requirements
No of Phase	3
Rated Voltage	380/11000 Volts
Rated Current	45.79 Amp
Rated Frequency	50 Hz
Flow	10.48 CUMEC
Head, Plant Efficiency	7m, 70%
KVA Rating	503.76 KVA

Cost Analysis of MHPP-1 (In Millions of Pak rupees) [15, 16, 17]

- Approx Cost of Kaplan Turbine 2.0 Mn
- 500 KW Generator cost 1.5 Mn
- Civil Work Appx cost 1.5 Mn
- Approx Labor Charges 0.25Mn
- Approx Transport Charges 0.25Mn
- Transformer Cost 1.0 Mn
- Switch Yard Cost 0.8 Mn
- Instruments/Measurement Cost 1.2 Mn
- Miscellaneous Expenditures 0.2 Mn
- **Total expenditures MHPP-1 8.7 Mn**

Combination of MHPP-2 and MHPP-3

MHPP-2 and MHPP-3 are proposed to be installed at the flow of main canal at 1.5 KM of upstream and 0.25 KM from downstream of main road bridge crossing respectively. Here the available head for both MHPPs is around 3 meters with less water quantity flowing because water will be diverted to Lasbella city. The available condition at sites of MHPP-2 and MHPP-3 can be referred to as power plants established on running river water [18]. Since the expected power generation from the individual turbines at both these sites would only yield 122.37 KW each (A total of 225.14 KW) so to obtain maximum power the best option seems to be laying of PRCC (Pre-stressed reinforced cement concrete) pipes slightly before setting up place of MHPP-2 which is then leading to the site of MHPP-3 in order to raise the water head from 3 to 7 meters as shown in figure 18 while figure 19 shows site for the alteration work for raising water head. In this way the expected electricity generation would be 311.34 KW. Table 4 enlists generator specifications for combined arrangement of MHPP-2 and MHPP-3 [14].

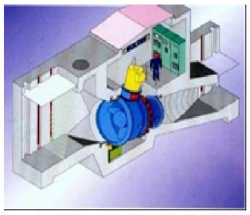

Figure 16: A View of Kaplan Turbine for MHPP-1

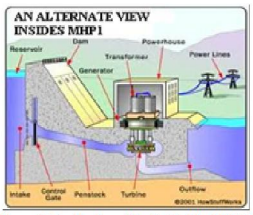

Figure 17: Inside view of Kaplan Turbine MHPP-1

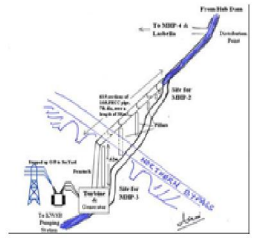

Figure 18: Civil Work Sketch for Raising Water Head from 3 to 7 meters

Figure 19: Site for Civil Work for Raising Water Head for MHPP-2 and MHPP-3

Table 4: Generator specifications for MHPP-2 & MHPP-3 (Cumulative) [14]

Generator Type	Requirements
Number of Phase	3
Rated Voltage	380 / 11000 V
Rated Current	311.34 KVA / 11KV = 28.30 A
Frequency	50 Hz
Flow (CUMECs)	5.95
Head & Plant Efficiency	7.62, 70%
Rated KVA	311.34 KVA each

Cumulative MHPP-2 & MHPP-3 cost analysis (In Millions Pak rupees) [15,16,17]

- Appx Cost of Kaplan Turbine 2.0 Mn
- Appx Cost of 500 KW Generator 1.5 Mn
- Appx Expenditure of Civil Work 1.5 Mn
- Appx Labor Charges 0.25Mn
- Approx Transport Charges 0.25Mn
- Transformer Cost 1.0 Mn
- Switch Yard Cost 0.8 Mn
- Instruments & Measurement Cost 1.2 Mn
- Miscellaneous Expenditures 0.2 Mn
- Total for single MHPP 8.7 Mn
- **Total Appx Expenditures of MHPP-2 & MHPP-3 17.4 Mn**

Micro Hydel Power Plant-4 (MHPP-4)

At the point from where canal is bifurcating into two branches (Karachi and Lasbella), four subsequent points with less than 3 meters heads each are available where MHPP-4 can be established easily in four parts named as MHPP-4(A), MHPP-4(B), MHPP-4(C) and MHPP-4(D). Since water heads where MHPP-4(A) and MHPP-4(B) is proposed is slightly more than 2.5 m, so installation of Kaplan turbines at these points is best. A maximum generation of 67.81 KW and 68.43 KW is estimated respectively from these two points. The other two points where MHPP-4(C) and MHPP-4(D) is proposed offer heads of 1.6 m and 1.4 m respectively thus require some alteration in order to raise the water head. The best option over here is to utilize 750 m long PRCC pipes structure as shown in figure 20. In this way a cumulative head of 6.8 meter will be available which can be used to generate an estimated power of 223.45 KW [19, 20, 21]. Figure 21, 22 and 23 show different sites for MHPP-4(A), (B), (C) and (D) respectively while table-5 shows generator specifications [14].

Cost calculation for Pre Stressed Reinforced Cement Concrete (PRCC) Pipes structure

PRCC pipes from the pipe factory of City District Government Karachi can be purchased for carrying out civil works for smooth flow of water with appropriate head. The total distance requires to be covered through PRCC pipes in this case is around 750 m (2461 ft) but the maximum length of one PRCC pipe is 16 ft, thus a total of 155 pipes are required. The cost calculations in million (Mn) of Pakistani rupees for this structure is as follows [22, 23];

- Cost of one pipe (16 ft Length) 0.08 Mn
- Total cost for 155 PRCC pipes 9.3 Mn
- Cost of one rubber joint Rs 5000/=
- 155 joint total cost (5000 x 155) 0.775 Mn
- Transportation charges 0.5 Mn
- Crane charges for one month 0.5 Mn
- Construction / labor charges 0.8 Mn
- Construction cost of 155 pillars 25 Mn
- Civil work cost (power house) 20 Mn
- **Cost of concrete structure, power house building and pipes 51.975Mn**

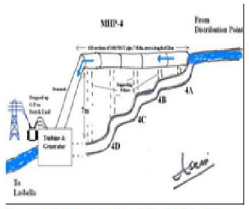

Figure 20: Civil Work Sketch for Raising Water Heads from 1.5 meters to 6.8 meters for MHPP-4

Figure 21: Proposed Location for MHPP-4 (A)

Figure 22: Proposed Location for MHPP-4 (B) & (c)

Figure 23: Proposed Location for MHPP-4(D)

Table 5: Generator specification MHPP-4 [14]

Generator Type	Synchronous Generator
Number of Phase	3
Rated Voltage	380 / 11000 V
Rated Current	223.45 KVA / 11KV = 20.31 A
Frequency	50 Hz
Flow (CUMECs)	4.53
Head & Plant Efficiency	7.18, 70%
Rated KVA	223.45K VA each

Total cost analysis of MHPP-4 (In Millions of Pak rupees) [15, 16, 17]

- Appx Cost of Kaplan Turbine 2.0 Mn
- Total cost for 4 Kaplan Turbine 8.0 Mn
- 4 x 500 KW generator cost 6.0 Mn
- Transformer Cost 2.0 Mn
- Switch Yard Cost 1.2 Mn
- Instruments & Measurement Cost 1.0 Mn
- Miscellaneous Expenditures 0.2 Mn
- Cost of concrete structure 51.975 Mn
- **Total Expenditures MHPP-4 70.375 Mn**

Transmission system schemes

Power generated from all these four MHPPs can be utilized in many ways as discussed below [24];

Option: 1

Each MHPP backed with a 380V/11000V step up transformer may feed 11000V bus bar to main feeding cumulative output to WAPDA colony substation at Hub Dam thereby reducing dependence on electricity requirement from Karachi Electric Supply Corporation (KESC).

Option: 2

Instead of connected all the MHPPs to 11000V Bus, power from each MHPP may be made available to WAPDA colony Sub Station at Hub Dam, local farm owners, crush plant operators and surrounding nearby villages. The buyer will have to pay all the expenditures occurred for the transportation of electricity like poles, conductors and wire in order to utilize this electricity.

Option: 3

The cumulative power generated from all MHPPs may be supplied to Hamdard University Karachi campus situated just 2 KM away from the generation / distribution point through the utilization of 11000V bus bar. In this way the university will be having its own generated power and so no dependence on KESC supply

Option: 4

The power generated after stepping up to 132 KV can be fed to WAPDA grid through the installation of appropriate switch yard / transformer station. This grid line supplying 132KV high tension power to Baluchistan passes just near MHPP-3, thus best location for installation switch yard at this point. The cost of such type of switch yard is Rs 2.5 Mn approx but KESC can connect a transmission line to switch yard station thus utilize this power in the main grid line available.

Recommended option / total estimated cost

The best possible option seems that total power generated from all MHPPs may be consolidated to WAPDA grid as proposed in option D. Overall expected cost for this recommended option is calculated as under;

Total Cost (In Million Rupees)

- Cost for MHPP-1 8.7 Mn
- Combined MHPP-2 & 3 cost 17.4 Mn
- Cost for MHPP-4 (Combined) 51.975 Mn
- 3 KM PRCC Channel cost (Distribution Point to MHPP-2 & 3) 96.5 Mn
- HT Cable (Conductors) and Poles (15 KM, 3 Phase) 50 Mn
- Transportation and Miscellaneous Expenditures 500 Mn
- **Grand Total 724.575 Mn**

For recommended scheme as discussed above KESC can be the sole consumer / buyer of this electricity generated developed through this work. However independent suppliers can also be the consumer / buyer of this electricity if not utilized by KESC (WAPDA colony and Hamdard University may be the alternative options).

Power system analysis

Apart from construction and design point of view power system analysis done depicts that the exact amount of electricity produced through all these MHPPs at Hub dam and its associated canals / distributaries is as follows;

- Net KVA Obtained 1100 KVA
- Power Factor 0.9
- Power produced 1038 KW (already calculated in table-2)

Proposed Tariff:

Presently Karachi Electric Supply Corporation (KESC), Pakistan is purchasing electricity from many electricity generation companies (GENCOs) at a rate of Rs 7/= per unit (KWHr) which can be negotiated in order to supply electricity at cheaper rate [25, 26].

Estimated turn over

- Installed generation capacity 1038 KW (Appx1 MW)
- Unit generated (1000X60SecX60 Min) 3600,000 KWHr
- Unit generated per annum (3600,000 X 4380) 1576.8 (12 hours daily operation)
- Selling Price for 1 KWH to WAPDA Rs 5.00
- Amount received in one year) 7884 Mn
- Break even time 6 Months
-

Conclusion

As a result of this applied work it is recommended that new MHPPs can be constructed on different locations at Hub Dam and canals emerging from this reservoir for producing electricity up to 1 MW. The amount expended for these MHPPs construction can be achieved within 3-4 years of its operation which is very economical. Moreover 1 MW of this electricity will be utilized to meet on going electricity crises of the country which is a step towards the combating the shortage of power in the country. This work will act as a source of motivation for the investors and government that non-conventional methods may be fruitful / beneficial if proper procedures are applied.

References

[1] P. Kiameh, "Hydel Power Generation Handbook, Selection, Application, Operation, Maintenance", Mc-Graw Hill, 1st Ed, 2002.

[2] P.K. Nag, "Power Plant Engineering", 3rd Edition, Tata-McGraw Hill, 2008.

[3] Brad Eck, "Case study of a World Bank Project: Dams in Pakistan", 2008.
[4] Prof. N. A. Khan, "Energy Recourses and Utilization in Pakistan", 1st Ed, 2010.
[5] Report on "Hydel Power Potentials of Pakistan", Private Power and Infrastructure Board (PPIB), Ministry of Water and Power, Government of Pakistan, 2003-04.
[6] Report on "Hydel Power Potentials of Pakistan", Private Power and Infrastructure Board (PPIB), Ministry of Water and Power, Government of Pakistan, 2006-07.
[7] Report on "Hydel power potentials of Pakistan", Private Power and Infrastructure Board (PPIB), Ministry of Water and Power, Government of Pakistan, 2011-12.
[8] "Series of Pakistan energy year books", Hydro Carbon Development Institute, Ministry of Petroleum and Natural Resources, Government of Pakistan, from 2001 to 2012.
[9] R. A. Chaplin, "Power plant technology", Vol-1, Encyclopedia of life support system, 1986.
[10] A. R. Inversin, "Directory of sources of small hydroelectric turbines and packages", 2nd Ed, USA Agency for international development under cooperative agreement decentralized hydropower international programs division, NRECA, Washington D.C. USA, 1981.
[11] O. Mgamga, G. Nyakoe, W. Kabecha, N. Abungn, "An experimental prototype for low head small hydro power generation using hydram", Jomo Kenyatta university of Agriculture and Technology, Nairobi, Kenya.
[12] "Pakistan integrated energy model (Pak-IEM)", Final report by international resources group Asian Development Bank/Ministry of Planning and Development, Government of Pakistan on Vol-1, Aug 2011.
[13] J.L. Gordon,P. Engg, " Hydropower Consultant, Turbine selection for small low-head hydro developments", in proceeding of the conference on innovative small hydro technologies, Buffalo, New York, USA 2003.
[14] Report by Thematic Network on small hydropower of the layman's guide book, "Guide on how to develop a small hydropower plant", European small hydropower association, Clso Penche, India, 1998
[15] Henry O. Egware, Albert I. Obanor, "Energy Cost Analysis of Incorporating Air Intake Cooling System in Omotosho Phase 1 Thermal Power Plant", Journal of Energy Technologies and Policy, Vol.3, Issue, 2013.
[16] G. Affidis, R. Rothschild, D. Howar, "The costs of small scale hydro power production impact on development of existing potential", Journal of Renewable Energy, Vol-35, pp.2632-2638, 2010.
[17] Maricic Tihomir, Karney W. Bryan, Pejovic Stanislav, "Essential role of technical review in hydro design", IEEE Electrical power conference, Montreal, Canada, 2009.
[18] El-Wakil M. M., "Power Plants Technology", 1st Edition, Mc-Graw Hill Book Company, New York, USA, 1984.
[19] "Standards / Manuals / Guidelines for small hydro development", Alternate hydro energy center, Indian institute of technology, Roorkee, India, 2008.
[20] Project report by Navigant consulting Inc. on "Statewide small hydropower resources assessment", Public interest energy resources program, California energy commission, USA, 2006.
[21] J. Gordon, "Hydro Review Boards-An important component for a successful development/Parametric Analysis of Pump turbine Sites", Electrical Power and Energy Conference, Montreal, Canada, Oct 2009.
[22] Final feasibility study on "Muskrat falls hydroelectric development", Vol-1, Engineering report, 1999.
[23] D.C. Jackson, "Boulder Dam: Origin of Siting and design", History Symposium, Bureau of Reclamation, 2002.
[24] J. Tepp and R. Weise, "Business opportunities in Pakistan for renewable energy", European renewable energy capacity building & match making project, 2008.
[25] Report on "Energy situation in Pakistan", Institute of Engineers Pakistan & Institute of Electrical and Electronics Engineers, Pakistan, 2013.
[26] Z. Mian, A. Nayar, "Pakistan & energy challenges", International perspectives of energy policy and role of nuclear power, 2010.

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