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A review on Optimization of Pakistan's Alternative Energy Resources at Domestic Level

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***Abstract*—Pakistan is struggling in providing a permanent source of energy to commercial and domestic users for last one decade. The power shortfall is increasing every year. Numerous efforts are in process, and some plans are in development phase. These efforts and plans consider the national level energy problems, having lead time of at least few years. Considering the warmness of summer especially in hot areas and in the month of Holy Ramadan, the temperature is beyond the comfort level which makes the condition worst. A systematic multi criterion decision analysis approach is used to evaluate the entire present domestic alternative power systems at the same level. Customer's requirements are gathered through survey and these are given weights using Analytical Hierarchical Process (AHP). Requirements are transformed into critical system's requirements (CSR) through Quality Function Deployment (QFD) Matrix. Multiple solutions available for this purpose are evaluated with Pugh Decision Matrix. The solution is the prioritized customer's requirements and domestic alternative power system which provides the best compromise of the customer's requirements**

Keywords—Domestic Power, Systematic approach, Analytical Hierarchical Process, Quality Deployment Matrix, Customer's Requirement, Pugh Decision Matrix

I. INTRODUCTION

Power production plays a major role in the progress of any country. Unfortunately Pakistan is going through a worst electricity catastrophe of all times. Uncontrollable floods, surplus sunlight, onshore windy areas of Sind, coal, nuclear and sources of geothermal energy are waiting for the effective power policies to be made. These policies need 5 to 10 years for the utilization of these resources. With too much involvement of technology and utilization of electric appliances in our daily lives, the energy crisis has disturbed the domestic life to a great level.

Energy deficit of Pakistan is increasing incredibly; this deficit will be triple by 2050. Employing combined cycle and heat recovery steam generators, 100 MW can be added against every 200 MW of existing capacity. Dams and nuclear power plants are also a better source for medium term plans, and for large term plans geothermal, ocean and hydrogen based fuel cells should be considered. [1]

The energy crisis in Pakistan is due to the faulty policies over the period of last thirty years. Distributed generation (DG) (Energy produced near the place of its use) has played an important role in the supplying the power in far and rural areas of many developing countries. It helps in reducing the power losses by theft, and through transmission. Distributed generation include combine heat and power, industrial gas turbines, solar, wind power, small hydro, biomass. Among other power solutions are privatization of the distribution system, energy efficiency plans and integrated electricity market in South Asia. [2]

The power crisis of the Pakistan is due to the higher prices of the hydrocarbons and ignoring the growing energy demand of the country. The fossil fuels have greatly impacted the environmental problems, therefore renewable energy utilization should be increased by research incentives, tax and duty reliefs to the renewable energy products. [3]

The energy problems in Pakistan can better be solved by the involvement of wind energy, solar energy, geothermal energy, ocean energy, biomass and fuel cell technology. Among renewable energy resources solar photovoltaic is a suitable source for small scale power generation, rural areas are a big source for biogas, wind energy is a potential source of power production, but efforts are still needed to be done to utilize the wind power effectively. Fuel cell and biomass technology also needs attention. The public awareness, research incentives, and counter checking the policies are the essential steps for the handling of the energy crisis. [4]

The progress of a country always rely on the resources of renewable and non-renewable energy resources of a country, Pakistan has big resource of natural gas but due to non-suitable conditions it is not accessible to the consumers.[5]

II. LITERATURE REVIEW

According to hydrocarbon development institute of Pakistan, 46.4 % of the total electricity produced is consumed by the domestic users. [Fig. 1][6]. Considering the importance of the power supply for the domestic users, the study is going to give an optimization of the alternative sources of power

available in the market during the shortage of grid power supply.

Numerous researchers have worked on energy solution at domestic level. Using the domestic boiler a domestic thermoelectric cogeneration system (TCS), can be designed with efficiency more than the state of the art thermoelectric applications. The systems provide the preheated feed water for domestic usage and power supply. [7]

The study shows the usability of the solar technology utilization for the region of Abbotabad, a survey is done which shows that solar energy technology is the best competitive technology for this region. [8]

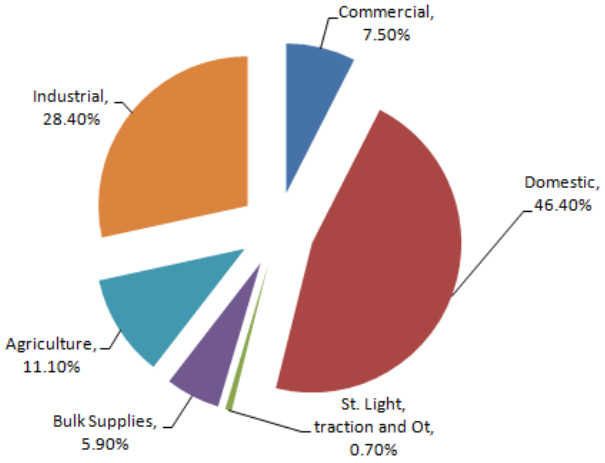

Fig. 1. *Electricity consumption by section 2011-2012 [6]*

III. METHODOLOGY

The steps involved in this study are explained one by one in Fig. 2.

For the collection of the data about the requirements a detailed public survey is done, by distributing the questionnaires to common people. The survey has served as input data which is then complied to get the finalized result.

Analytical Hierarchical process (AHP) is a technique to used to solve decision making problems, which involves an overall goal, requirements, systems to be evaluated. It is a structured process, where requirements are decomposed into basic requirements and comparison of the alternatives is made at each level of requirement decomposition. Decision is evaluated over the results of all the comparisons. [Saaty, 1980]

AHP has been used for prioritizing the Pakistan's renewable energy resources. An evaluation is made considering the criteria related to technical, social, political, environmental issues. The resources considered in this evaluation are wind, solar photovoltaic, solar thermal, and biomass. [9]

It is a versatile technique can be used in combination with other tools e.g. TOPSIS technique, Quality deployment matrix etc [10, 2].

The study is going to use the AHP matrix for weighting the customer's requirements.

Quality Function deployment matrix was introduced at Mitsubishi for the first time. The main function of the QFD is to transform user's requirements into detailed design specification. It is technique used to transform the customer's voice into the designer language. [11]

In this study QFD use the customer's requirement which are the result of AHP matrix in the first column and converts these requirements into critical system requirements (CSR). The weights of the AHP matrix are used as requirement importance in QFD. QFD is being used here to the give the CSR a priority number, which is a key for the selection method.

Pugh has proposed a decision making method consisting of evaluation of the systems against the prioritized criteria with a baseline system. The systems are considered better or worse while comparing with the baseline system and given a relative number, finally prioritized summation of the systems column wise gives a score to each system, then the system having the highest score in considered the best system.[12,13]. The CSR from QFD will be used as criteria in Pugh Matrix.

A study has used the same methodology for the evaluation of the molecular methods to be used in international space station for the feasibility of the crew and finding coherence with microbial monitoring system requirement. [14]

Another study which has used the same methodology has developed three novel solar thermal collectors and evaluated them by the use of AHP, QFD and Pugh Matrix. It is quoted to be a relatively complex technique, but technical priorities attained through this procedure are quite useful. [15]

IV. SURVEY

A questionnaire is distributed at different levels of the society. The results of the survey are schematically synthesized to get the following outcomes

- Voice of the customer (Customer's requirements)
- Alternate energy resources
- The relationships of the customer's requirements to each other and with the alternative energy resources.

Figure 3 shows the alternative energy resources and customer's requirements, but the relationships are used in filling the AHP, QFD and Pugh matrix. The definitions of the different alternative energy resources found are as under

1. Petrol generator is the generator designed for petrol as a fuel.
2. Diesel generator is the generator designed for diesel as a fuel.
3. Solar system stands for the solar photovoltaic system installed with battery, inverter and other accessories.
4. Low pressure generator (LPG) generator is the low pressure gas generator; where a gas kit is installed in the generator to replace petrol with LPG.

5. Natural gas generator is the petrol generator with a gas kit installed on it, to be used on natural gas as a fuel.

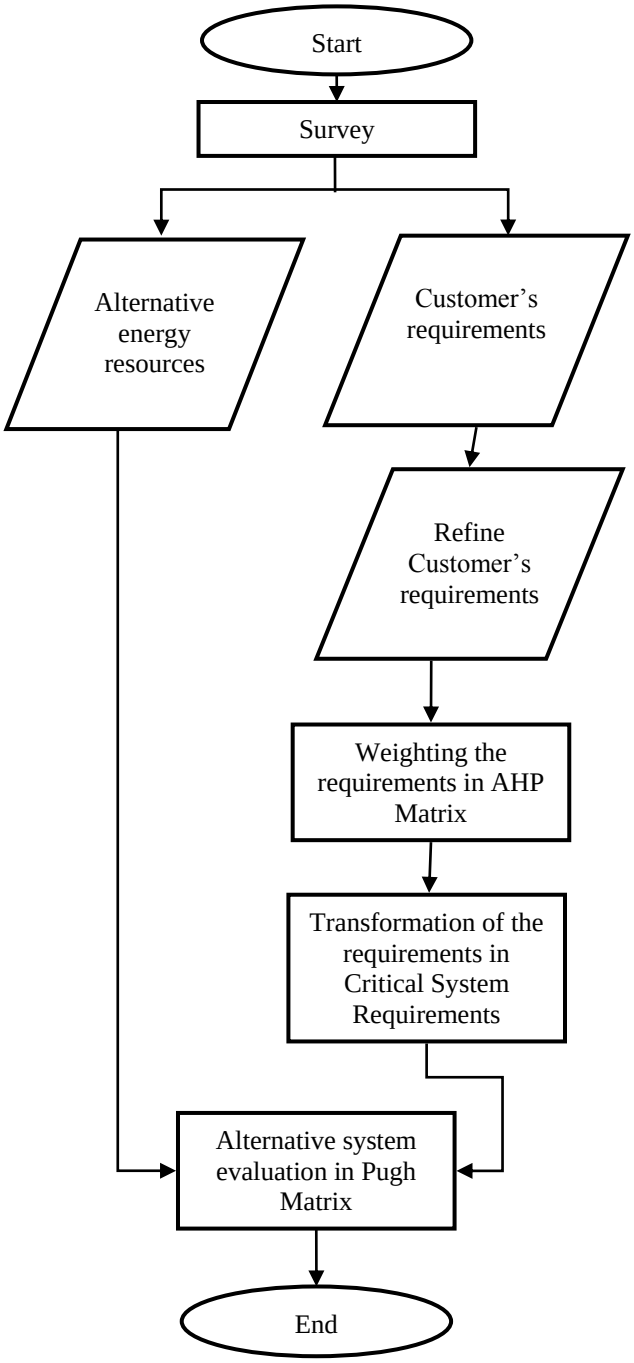

Fig. 2.*Flow chart of the methodology*

6. Uninterruptible power supply system (UPS) is a system which gets charging from grid power and use this power when the grid supply is not available.
7. Hybrid solar and UPS is the combination of UPS and solar photovoltaic.

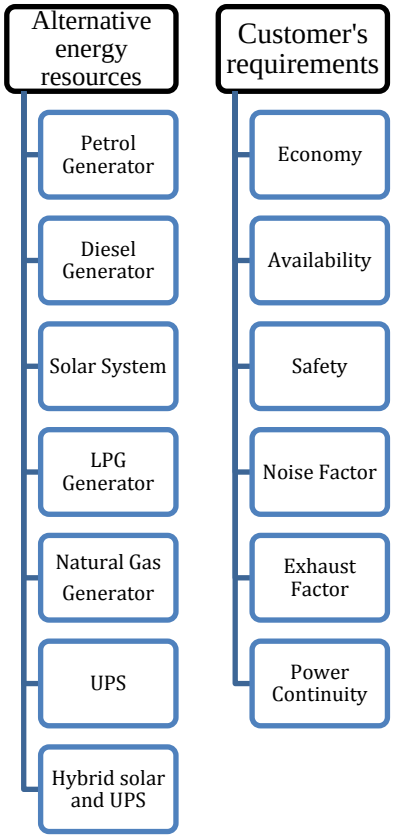

Fig. 3. *Outcome of the survey*

V. Analytical Hierarchical Process

The voice of the customer gathered in survey is used as an input data for AHP matrix. Table I shows the scale used in AHP matrix for ranking the customer's requirement. The boxes in AHP matrix are filled by ranking the requirements relative to each other. The detailed AHP Matrix is shown in table II. The Criteria are defined as under

1. Economy stands for the all types of cost involved in implementing a power solution.
2. Availability stands for the total time the system is available for operation.
3. Exhaust factor is the smoke control or exhaust piping required to keep the smoke to least disturbing place.
4. Noise factor is the sound control unit installed.
5. Safety means the danger during operation.
6. Power continuity means degree of continuity of the power.

In order to find the weight age of each factor, the matrix has been normalized column wise and normalized row sum has been calculated by adding the rows of that normalized matrix.

TABLE I. Scale used in AHP Matrix

Scale	
1	Equally Important
3	Somewhat more important
5	Moderately more important
7	Strongly more important
9	Extremely more important

VI. Quality Function Deployment Matrix

QFD is used to transform the customer's requirements into CSR. Table III shows the detailed QFD Matrix. The CSR are defines as under

1. E1 Capital cost is the total material or capital cost.
2. E2 Space cost is the cost of the space where the system is to be installed.
3. E3 Running cost is the fuel cost and oil changing cost.
4. E4 Installation cost is the cost for the installation of the power system.
5. A1 Maintainability is the time required to maintain the power when get failed.
6. A2 Reliability is the time a system performs the specified function under the specified operating conditions.
7. A3 Total life is the total spam of time the system is available.
8. S1 Vibration factor is the vibration hazards.
9. S2 Safe to handle is all other hazards
10. The relationship is made between customer's requirements and CSR, through survey data and expert opinion. CSR is given a priority number by multiplying each value in specific CSR with corresponding weights, then adding them in a certain column. Figure 4 shows the bar chart of the prioritized criteria, it shows that the safety, capital cost, space allocation cost is among the high priority weights, noise and exhaust control are among the least important criteria.

VII. Pugh Decision Matrix

Considering petrol generator as baseline, values for all other systems are calculated against all the CSR. The systems are given a value between 5 to -5, where 5 shows that the performance of the system is much more than the petrol generator, -5 shows that the performance of the system is much lower than the petrol generator and zero shows that the performance is same as petrol generator. After assigning the values, the performance numbers for all the systems are calculated, which gives the relative optimization of the systems with respect to petrol generator. Table IV shows the detailed Pugh matrix.

TABLE II. ANALYTICAL HIERARCHICAL PROCESS

Customer's Requirements	Economy	Availability	Exhaust factor	Noise factor	Safety	Continuity of the power supply	Normalized sum	Weights
Economy	1	3	3	3	5.00	3	1.98	0.33
Availability	0.33	1	3	3	1	5	1.21	0.201
Exhaust control	0.33	0.11	1	1	0.11	0.33	0.3	0.05
Noise control	0.33	0.11	0.33	1	0.11	0.33	0.26	0.043
Safety	0.20	1	9	9	1	0.2	1.29	0.215
Continuity of the power supply	0.33	0.11	3	3	5	1	0.97	0.161
column sum	2.52	5.33	19.33	20	12.22	9.86		

TABLE III. Quality Function Deployment Matrix

Sr #	1 Weak 3 Moderate 9 Strong Black None Requirements	Weights	E1:Capital Cost	E2: Space cost	E3:Running Cost	E4:Installation cost	A1:Maintainability	A2:Reliability	A3:Total Life	Exhaust factor	Nosie factor	S1:factor Vibration	S2:Safe to handle	Continuous Power Supply
1	Economy	0.33	9	9	9	9	3	3	9	3	3	3	9	3
2	Availability	0.20	9		3	3	9	9	9					9
3	Exhaust control	0.05	3	3	3	3	3	3	3	9	9		3	
4	Noise control	0.043		9		3		1	1	1	9	9	3	
5	Safety	0.21	3	9		1	1	1	1	3		9	9	
6	Power Supply	0.16					3	3	3	3	3	1	9	9
7	Priority	0.33	5.58	5.44	3.72	4.06	3.64	3.69	5.67	2.61	2.31	3.47	6.63	4.24

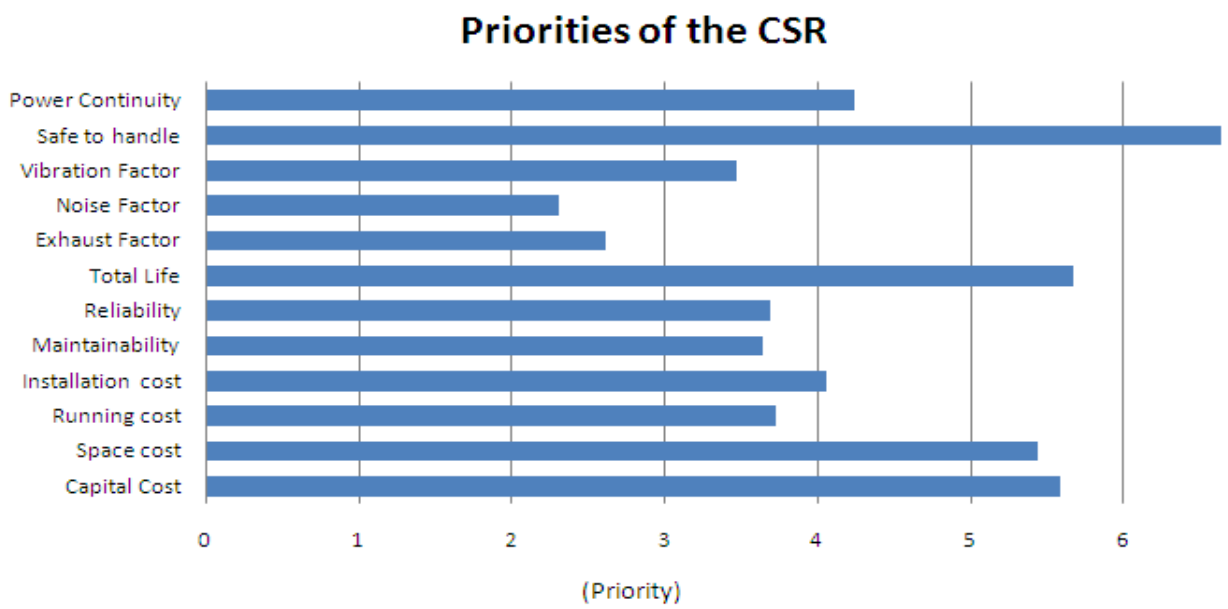

Fig. 4. *Priorities of critical system's requirements (CSR)*

TABLE IV. PUGH MATRIX

Critical System's Requirements	Priory Index	Petrol Generator	Diesel Generator	Hybrid Solar and UPS	Solar System	UPS	LPG Generator	Natural Gas Generator
Capital Cost	5.58	0	1	-5	-3	0	-1	-1
Space allocation cost	5.44	0	0	-4	-4	3	0	0
Running Cost	3.72	0	0	-1	-1	1	0	0
Installation Cost	4.06	0	0	4	5	2	2	3
Maintainability	3.64	0	0	-3	-2	0	0	0
Reliability	3.69	0	0	3	5	1	-1	-2
Total Life	5.67	0	1	3	5	-4	-1	-1
Exhaust Factor	2.61	0	0	5	5	5	1	1
Noise Factor	2.31	0	-2	5	5	5	0	-1
Vibration Factor	3.47	0	0	5	5	5	0	0
Safe to handle	6.63	0	-1	1	2	0	0	0
Continuity of Power Supply	4.24	0	0	5	-2	-3	-1	0
		0	0	52.28	62.41	42	-9.13	-7.17

VIII. RESULTS

The priorities of the technical requirements through the use of QFD and AHP have supported the valuable comparison of the energy systems. Since the petrol generator has been selected as the baseline therefore it gained the performance number of zero, the alternative sources having a performance number more than zero are better than petrol engine and the others having performance value less than zero has performance less than the petrol generator. From Figure 5 it is clear that among all the alternative energy resources the solar energy has the best performance score and it best fulfills the voice of the customer, it has the performance score of 62.41. Hybrid system has the score of 52.28 and it is on second place, UPS is on third place with the performance score of 42. Diesel generator has the same performance score as that of the petrol generator. LPG generator and natural gas generator are among the worst for their poor total life and high maintenance expenditures. For future work the criteria can be used as a base for the designing of a new concept which will completely fulfill the user's requirements.

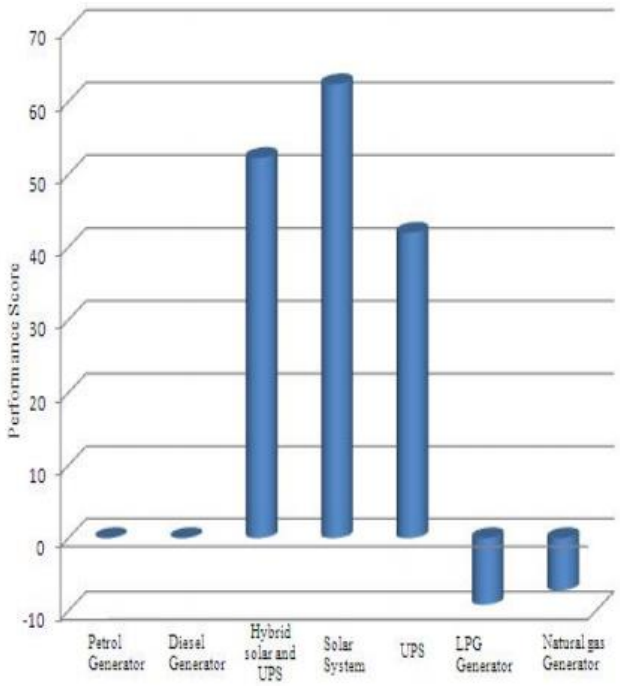

Fig. 5. *Comparison of the performance score of the alternative energy systems*

IX. Conclusion

The study has used the AHP, QFD and Pugh matrix as one of the multi criterion decision analysis. The alternative energy resources being used in Pakistan during the shortage of grid power supply has been assigned a performance score against the prioritize criteria. With the increase in complexity of the system the technique can be used in solving the decision problems efficiently. The method is useful at all levels and should be implemented at the national energy planning or evaluation of the existing energy solutions where the new concepts being proposed for the solution of the power crisis.

X. Acknowledgment

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