Energy for Sustainable Development 36 (2017) 16–21

Contents lists available at ScienceDirect

Energy for Sustainable Development

An analysis of the effects of residential uninterpretable power supply systems on Pakistan's power sector

Naveed Arshad *, Usman Ali

Department of Computer Science, LUMS, Sector U, DHA, Lahore, Pakistan

ARTICLE INFO

Article history:
Received 12 September 2015
Revised 20 August 2016
Accepted 17 September 2016
Available online 12 November 2016

Keywords:
Uninterpretable Power Supply System
Load Shedding
Energy Efficiency
Measurement
Power Sector

ABSTRACT

For the past many years Pakistan is facing electricity shortfall. The gap between demand and supply of electricity is as much as 6000 MW during the peak summer months. This has resulted into scheduled power cuts that range between 6–12 h in a day. To reduce the effect of these power cuts or load shedding, consumers have installed alternate energy sources such as Fossil Fuel Generators and Uninterpretable Power Supply Systems (UPSs). While Fossil Fuel Generators use energy sources such as oil and natural gas, the UPSs are charged from the electricity grid that is already under stress. Some sources estimate the UPSs penetration to as much as 40% in Pakistan. With this penetration rate the UPSs are a solution for individual consumers but it exacerbates the problem at the National scale. Moreover, the low quality of UPSs further strains the electricity system. In this paper presents a study to investigate the effects of UPSs in Pakistan's electricity system. By carrying out measurements of sample UPSs we estimated the amount of electricity the UPSs consume in Pakistan's electricity market. Our results show that depending on the number of power cut hours, the UPSs consume between 2%–7% of electricity at any given time. We further provide ways and measures to reduce the UPS charging load on the overall electricity system.

Introduction

Pakistan is facing demand and supply shortfall in its power sector. The total electricity requirement of the country peaks to approximately 20,000 MW during the summer months. Of this peak demand, the country faces a shortage of around 5000 MW due to inadequate supply (Nayyar et al., 2014). This results in load shedding of up to 12 h per day (Amer and Daim, 2011). To mitigate the effects of this load shedding many people in the country use alternative measures such as Uninterrupted Power Supply (UPSs) and fossil fuel generators. Generators use gasoline, diesel or natural gas to generate electricity but UPSs are charged from the same electricity distribution grid. The efficiency of UPS is up to 94% depending on the load, battery-type, inverter and its usage style (Gurrero et al., 2007). Some UPSs are reported with even higher efficiencies (Moura et al., 2015). However, this high efficiency is for branded UPSs which are designed with state-of-the-art components.

In Pakistan, the UPSs available off the shelf and being bought and used in the residential and small scale commercial sectors do not have this efficiency level. This inefficiency of the UPSs put extra load on the grid and creates more problems for it. A large number of people, with access to credit and the market have bought UPSs for running essential electrical devices during the times of power unavailability. Although this is a legitimate use of UPSs, it is limited to the more affluent section of society due to high upfront cost of purchase (Pasha and Saleem, 2013). But the most common UPS (1–3 kVA) typically used in households are highly inefficient. The losses of such UPSs are accumulated due to the inversion, storage and rectification losses of charging and discharging cycles

In this study we undertake such an exploration with the hope that the evidence produced leads to the promotion of alternative sources of energy for backup power, thus reducing the load on a National Grid in crisis. In our quest we bought five random UPSs from the market and measured their efficiency. Following this we used approximations of the number of UPSs used in Lahore, the second largest city of Pakistan, to estimate how much power is wasted due to use of inefficient UPSs. To show possible national level impact, we also extrapolate these results to the whole country. Towards the end we discuss alternate solutions to the uncontrolled use of UPS and discuss how alternate energy sources such as solar and wind can be used to reduce the load on National Grid.

Introduction to Pakistan electricity system

Pakistan, with an area of 796,095 km^2, is the second most populous country in South Asia after India and sixth in the world with population of 177.1 million according to official estimates. The population growth rate in Pakistan is around 2% per year. With current population growth rate it will become the fifth most populous nation by 2050 (Ahmed

* Corresponding author.
E-mail addresses: naveedarshad@lums.edu.pk (N. Arshad), usman.ali@lums.edu.pk (U. Ali).

http://dx.doi.org/10.1016/j.esd.2016.09.004
0973-0826/

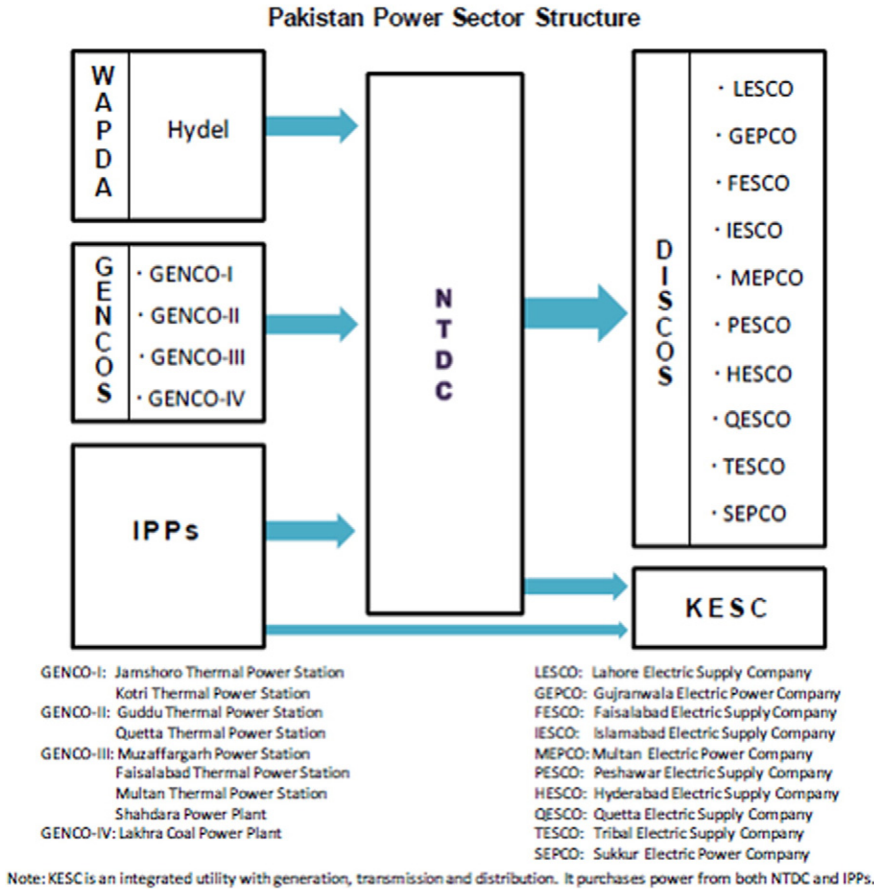

Fig. 1. Pakistan Power Sector Structure.

et al., 1992). Due to population growth there has been an unprecedented increase in demand for energy during the last decade. During this time the supply has failed to match this growing demand (Dar et al., 2013).

According to the Economic Survey of Pakistan (2014) the total installed systems of the PEPCO[1] generated 22,797 MW out of which 14,635 MW were obtained from fossil fuel including 35.2% oil and 29% gas, 6611 MW from hydro production (29% of total) and 1322 MW (5.8% of total) from nuclear sources (Economic Survey of Pakistan, 2014-15).

Under PEPCO there are four major power producers in Pakistan:

(1) Water and Power Development Authority (WAPDA)
(2) Karachi Electric Supply Company (KESC)
(3) Independent Power Producers (IPPs)
(4) Pakistan Atomic Energy Commission (PAEC)

WAPDA is responsible for a total power generation of 11,272 MW from thermal and hydroelectric sources. Depending on the flow of water, hydel electricity generated by WAPDA varies between a minimum of 2414 MW and a maximum of 6761 MW. KESC generates a total of 1756 MW. IPPs share in power generation is 7070 MW while PAEC generates 852 MW of electricity. By combining all four power producers, Pakistan's maximum power generation capacity is 21,143 MW. Of course not all the generation capacity is available all the time. The effective generation capacity in peak summer months is close to 20,000.

Pakistan experiences extreme shortage of electricity during both summers and winters. During the summer the demand increases at higher rate than supply due to increased use of high power consumption devices, such as air conditioners (over 5000 MW of power demanded), while in the winter low hydel availability drastically reduces the supply.

PEPCO also manages 10 Power Distribution Companies (DISCOs) and one TransCO (NTDC). The ten DISCOs are responsible for power distribution to end users. KESC meets its overall demand with its own generation plus purchase from NTDC, IPPs and from Karachi Nuclear Power Plant (Anon., nd-b). Fig. 1 shows the current structure of power sector.

Energy crisis and alternative sources

The increase in power outages and load shedding in Pakistan spurred the demand for generators and UPSs, with a majority of commercial buildings and significant percentage of residential buildings

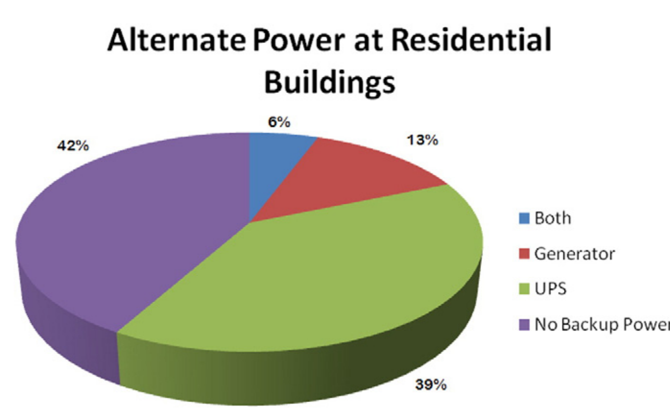

Fig. 2. Alternate Power Usage in Pakistan (Anon, 2012)

[1] Pakistan Electric Power Company (PEPCO) is the governmental agency in Pakistan that coordinates the generation, transmission and distribution of electricity.

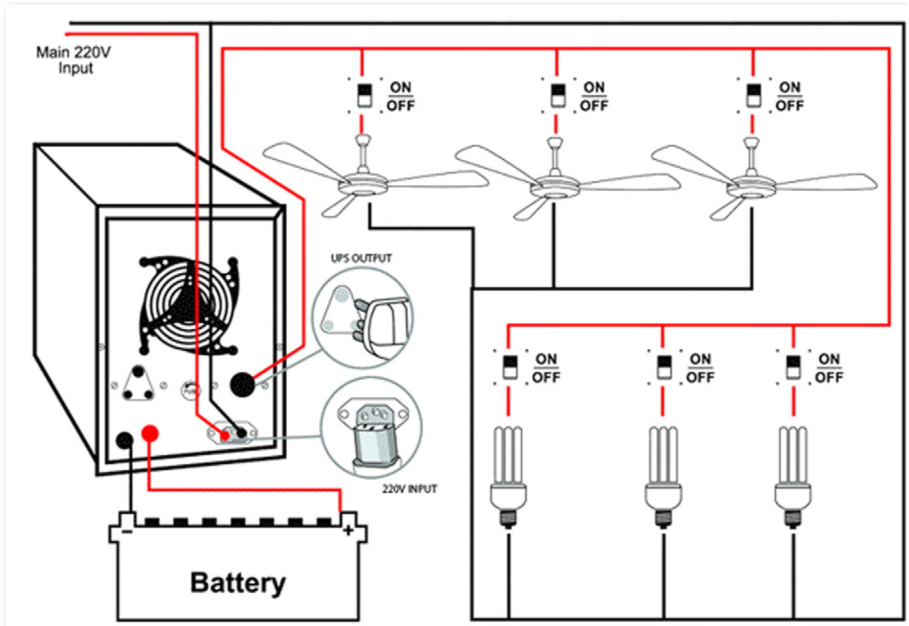

Fig. 3. UPS system diagram.

adopting alternative power sources (Gurrero et al., 2007). An online survey was conducted from 4th July 2012 to 10th so July 2012 by a top ranked Pakistani website Rozee.pk to find out the most common problems faced by the citizens of Pakistan due to load shedding or frequent power failure. A total of 3000 respondents participated in the survey and answered 15 questions related to energy. 76% of the respondents said that power failures have significantly increased during recent months while 1.5% claimed that power failures had decreased. Overall 42% of respondents reported that they had no backup power facility at home. Among the rest, 39% used UPSs, 13% used generators and 6% used both. In commercial buildings 51% working professionals reported continuous supply of power at office through generators, 16% reported the use of UPSs, 24% use both generator and UPSs, while 9% reported that no backup power facility had been installed. A graph of alternate power usage is shown in Fig. 2 (Anon, 2012). In another survey conducted by Gallup Pakistan, 24% of respondents claimed to use UPSs during load shedding (Anon., nd-a).

According to another research paper, discussing the impact and cost of electricity vis–vis load shedding to domestic consumers, 28% of household used generators while 30% used UPSs. Table 1 shows percentage of households by level of consumption expenditure with a Generator and/or UPS in Pakistan (Pasha and Saleem, 2013). In summary it is safe to say that at least 30% of all commercial and residential buildings in Pakistan use UPS. We will use this number to calculate the effects of UPS usage on the overall energy crisis in Pakistan in later sections.

Table 1
Percentage of households by level of consumption expenditure with a Generator and/or UPS in Pakistan.

Level of monthly consumption expenditure (Rs) with generator with UPS	With generator	With UPS
0–15,000	2	4
15,001–35,000	17	26
35,001–70,000	45	47
70,001 and above	75	43
Overall	28	30

Uninterrupted power supply(UPS)

UPS is a system that provides backup power to critical loads in cases of power outages. UPS systems have two main components: inverter and battery. The inverter converts the voltage from an AC voltage to DC voltage and vice versa. The battery stores the energy using DC voltage. The UPS is charged from grid. However, when the grid is shut down, the UPS system automatically takes over and starts supplying electricity to all or selective loads in the building. The UPS works until its battery is exhausted. Fig. 3 shows the diagram of a typical UPS system.

Types of UPS systems

For our study since we are interested in finding efficiency of the UPS as one single entity without going into the detailed of its efficiencies of its various components. To this end we divide the UPSs into two main categories. The first covers UPSs that are developed by international companies and these are available easily in the Pakistani market. The second are UPSs designed and manufactured by local companies using basic and rudimentary components, in order to keep the purchasing cost of the UPS low.

Types of batteries

Battery is the second essential component of a UPS (Nair and Garimella, 2010). Most of the UPSs being used in Pakistan use flooded lead acid batteries. These are the same batteries that provide start-up

Table 2
UPS Efficiency Results.

UPS make	Battery	Load	Overall efficiency (%)
Brand 1	12 V	200 W	51.09
Brand 2	12 V	200 W	49.72
Brand 3	12 V	147 W	48.13
Brand 4	12 V	110 W	44.1
Brand 5	24 V	265 W	53.56
Average			50.68

Table 3
Wastage of energy by UPS under various loads (in kWh).

Wastage	40% Load	50% Load	60% Load	70% Load	80% Load	90% Load	Aver age
Hourly	0.13	0.16	0.2	0.23	0.27	0.3	0.22
Daily	1.05	1.32	1.59	1.86	2.14	2.41	1.73
Monthly	31.41	39.6	47.61	55.91	64.09	72.19	51.8

power to cars and trucks. These batteries are not the most optimal option for a UPS because they are designed to provide an initial current surge which drops very sharply. The alternative option is a deep cycle gel battery. These batteries are typically expensive but provide a longer life and better current output. However, since the most commonly used UPSs in Pakistan use the former (presumably due to their cheap cost and wide accessibility), for our study we have assumed that lead acid batteries are used in all cases.

UPS efficiency

Our goal in this study is to analyze the impact of UPS usage on the national electricity supply in the context of the current power crisis. Since there are a numerous brands of UPSs available we selected at random five UPS brands. Three of these brands are locally manufactured while the other two are Chinese manufactured. The rating of each of these UPSs is roughly 1 kVA.

Since the goal of this study is to find the contributions of UPSs in the overall power crises, we considered the UPS as a black box. This means that we use the UPS as a consumer would use for charging and discharging as a complete entity which consists of inverter, batteries, charging, discharging algorithms etc. We did not take into account the efficiency of batteries and inverters individually. We charged the UPSs with the electricity from the National Grid and discharged it to see how much power each could supply back to the electrical devices connected to it.

UPS efficiency results

We ran our experiments multiple times with the same loads. The results of the combined charging and discharging efficiencies of the five UPSs are given in Table 2.

In our experiments, we charged each UPS and measured the units of electricity (in kWh) that they take to charge completely. Upon fully charged, we discharged each UPS with the same type of constant load and calculated the number of kWh it gives as output. We used constant resistive loads of light bulbs that draw the same amount of power zduring its operation (Barker et al., 2013). The efficiency was calculated by subtracting the kWh used for charging with the kWh supplied by the UPS while discharging.

According to our experiment, UPS efficiency ranges between 44.10% and 53.56% with an average of 50.68%. These numbers are starkly different from the UPS efficiency of 94% or more as mentioned in (Gurrero et al., 2007; Moura et al., 2015). This stark difference is due to the use of inefficient inverters and lead acid type batteries that are usually used in cars and trucks.

Table 4
Categories of LESCO Users.

Type of connection	# of users
Residential	2,587,000
Commercial	476,706
Industrial	65,695
Bulk supply	481
Tube wells	50,427
Others	1984

Table 5
Breakdown of LESCO kWh Usage by Residential Consumers.

kWh	Percentage
50 or less	3.4%
50–100	15.2%
101–300	65.5%
301–1000	15.3%
1001 or more	0.5%

UPS efficiency vs. load

The aforementioned efficiency of the UPS is calculated with 100% battery exhaustion. However, in the case of everyday scheduled load shedding 100% discharge is rare. Table 3 contains UPS charging efficiency of the same UPSs based on 40%–90% battery exhaustion. We assume up to 8 h of load shedding daily. In this calculation we used the average efficiency of 50.68% and assumed 1kVA UPS having a maximum load of 0.670 kW. This load is the average hourly load for households which use UPSs. The numbers in the following table show the energy wasted in kWh for each hour, day and month due to the inefficiency of the UPSs. With only a small UPS of 1 kVA with a 0.670 kW load and with 8 hours of load shedding the UPS wastes slightly more than 51 kWh per month.

UPS effects on utility

After calculating the efficiency of individual UPSs we use this efficiency to calculate the wastage of energy by UPS in Lahore, the second most populous city of Pakistan. The Lahore Electric Supply Company

Table 6
kWh waste under various loadshedding hours vs. load for a single UPS (in kWh).

Hours of load shedding/load percentage	50% Load	60% Load	70% Load	80% Load	90% Load	Average kWh Waste	Average Monthly kWh waste
1	0.16	0.2	0.23	0.27	0.3	0.23	6.96
2	0.32	0.4	0.46	0.54	0.6	0.46	13.92
3	0.48	0.6	0.69	0.81	0.9	0.7	20.88
4	0.64	0.8	0.92	1.08	1.2	0.93	27.84
5	0.8	1	1.15	1.35	1.5	1.16	34.8
6	0.96	1.2	1.38	1.62	1.8	1.39	41.76
7	1.12	1.4	1.61	1.89	2.1	1.62	48.72
8	1.28	1.6	1.84	2.16	2.4	1.86	55.68
9	1.44	1.8	2.07	2.43	2.7	2.09	62.64
10	1.6	2	2.3	2.7	3	2.32	69.6
11	1.76	2.2	2.53	2.97	3.3	2.55	76.56
12	1.92	2.4	2.76	3.24	3.6	2.78	83.52

Table 7
LESCO kWh wasted due to UPS usage in 24 h (in kWh).

Hours of load shedding	50% Load	60% Load	70% Load	80% Load	90% Load	Average kWh waste
1	124,176	155,220	178,503	209,547	232,830	180,055
2	248,352	310,440	357,006	419,094	465,660	360,110
3	372,528	465,660	535,509	628,641	698,490	540,165
4	496,704	620,880	714,012	838,188	931,320	720,220
5	620,880	776,100	892,515	1,047,735	1,164,150	900,276
6	745,056	931,320	1,071,018	1,257,282	1,396,980	1,080,331
7	869,232	1,086,540	1,249,521	1,466,829	1,629,810	126,0386
8	993,408	1,241,760	1,428,024	1,676,376	1,862,640	1,440,441
9	1,117,584	1,396,980	1,606,527	1,885,923	2,095,470	1,620,496
10	1,241,760	1,552,200	1,785,030	2,095,470	2,328,300	1,800,552
11	1,365,936	1,707,420	1,963,533	2,305,017	2,561,130	1,980,607
12	1,490,112	1,862,640	2,142,036	2,514,564	2,793,960	2,160,662

Table 8
Detailed breakup of demand supply of electricity in Punjab as on 3rd October 2013.

Discos	Supply (MW)	Demand (MW)	Domestic load shedding (hrs)	Industrial load shedding (hrs)	Shortfall (MW)	Shortfall (%)
LESCO	2253	3112	5–6	4	859	28%
GEPCO	992	1473	7	3–12	481	33%
FESCO	1330	1875	7–8	6	545	29%
IESCO	1165	1595	6	8	430	27%
MESCO	1669	2576	7–10	2–8	907	35%
Pun jab Total	7409	10,631			3222	30%

Table 9
Average UPS wastage in different electricity companies in Punjab and Federal Capital Area.

Discos	LESCO	GEPCO	FESCO	IESCO	MEPCO	Total
Load 40%	101.6	44.7	64.2	52.5	75.3	338.4
Load 50%	128	56.4	77.2	66.2	94.8	422.7
Load 60%	154	67.8	90.7	79.6	114	506.1
Load 70%	180.8	79.6	103.8	93.5	133.9	591.6
Load 80%	207	91.1	117	107	153.3	675.5
Load 90%	233.3	102.7	84	120.6	172.8	713.5
Average (MW)	167.4	73.7	89.5	86.6	124	541.3

(LESCO) supplies electricity to Lahore and its adjoining areas. Table 4 shows the LESCO divisions of end users. LESCO had about 3 million customers on 30th June 2010, out of which the vast majority (81%) were residential.

Based on average kWh usage, domestic consumption can be broken down in Table 5.

From this breakdown we gather that over 70% of households use more than 100 kWh. Combining this with our deduction earlier that 30% of domestic users use UPSs, we reach the approximation that around 700,000 households have a UPSs of 1 kVA each in the area served by LESCO. Table 6 shows that between 0.23 and 2.78 kWh are wasted if the load shedding is of 1 h or 12 h respectively by a single UPS. For the same hours of load shedding, the average monthly wastage becomes 6.96 and 83.52 kWh, respectively.

Table 7 we have provided an analysis of the various load shedding hours and the respective kWh lost in charging/discharging cycle for an estimated 776,100 UPSs installed at 30% of total domestic users getting electricity from LESCO.

In conclusion LESCO consumers consume around 54 million kWh in 24 h period. With twelve hours of load shedding the kWh wasted by UPSs inefficiency is around 2.1 million as stated in Table 7. This means that around 3% of the electricity that could be otherwise utilized for other purposes is wasted.

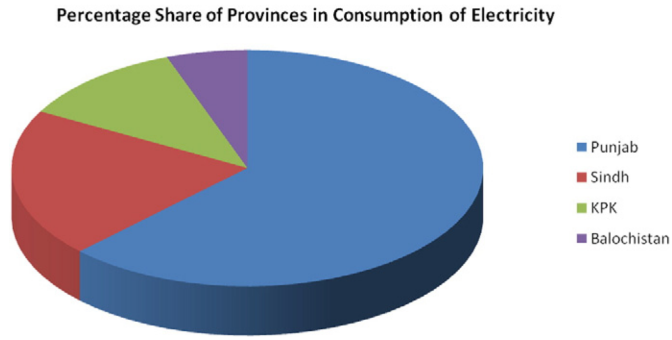

Fig. 5. Percentage share of provinces in consumption of electricity.

Role of UPSs in aggravating the National Energy Crisis

Punjab, the most populated province in Pakistan, accounts for 68% of the overall consumption of electricity, 65% of GDP and 60% of industry, with more than 48,000 industrial kWh. Since most of the industries of Pakistan are located in Punjab, they are particularly adversely affected by regular load shedding lasting from 7 to 8 h. DISCOs in Punjab are more efficient as compared to other provinces.

Table 8 presents the results of a survey conducted on 3rd October 2013, showing the demand and supply of electricity for all the DISCOs in Punjab. Punjab has a total of 10,361 MW demand of electricity while the supply is 7409 MW. The excessive demand for electricity ultimately results in load shedding occurs which lasts for a minimum of 5–6 h reaching a maximum of up to 7–10 h. Therefore the percentage shortfall between demand and supply is 30.31%, as shown in Table 8 (Department Research And Development The Lahore Chamber of Commerce, 2013).

Table 9 and Fig. 4 bar chart describes the aforementioned table to relate the demand and supply of electricity in Punjab as of 3rd October 215 2013.

The DESCOs in Punjab according to Table 8 have a shortfall of 28% to 35%. Using this shortfall and assuming 30% of users have UPS the range of energy wasted in Punjab due to UPS inefficiency stands between 1% and staggering 7% with 1 h of load shedding and 12 h of load shedding respectively Table 9.

Fig. 5 demonstrates the 4 province electricity consumption in which Punjab consumes more than half of the electricity generated in Pakistan i.e. 62%.while others has average electricity consumption. The reason behind the usage of electricity in Punjab is its population and the agglomeration of industries in this region.

While conducting the survey, we found that the efficiency of every UPS in converting power to AC and DC is approximately 50%. Table 10 shows the consumption and wastage of UPSs across all 4 provinces of

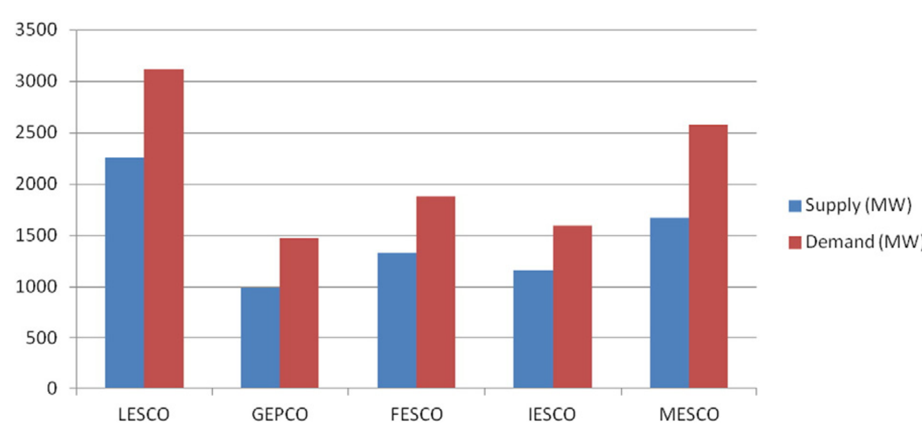

Fig. 4. Demand supply of electricity in Punjab.

Table 10
UPS Energy Wastage in Pakistan Provinces.

Provinces	Consumption MW	UPS wastage MW
Punjab	14,805	1036
Sindh	4754	332
KPK	2683	187
Baluchistan	1294	91
Total	23,538	1648

Pakistan, with national consumption and wastage at 23,538 MW and 1647.7 MW, respectively.

The aforementioned table is the summary of our analysis of the contribution of UPS usage to the national energy crises. According to our calculation up to 7% of electricity is wasted in UPS usage. The irony is that UPS usage increases when the energy shortfall increases. This means when UPS usage is increased the electricity shortfall increases further due to the inefficiency of UPSs commonly used. With every extra hour of load shedding the UPS charging contributes to aggravating the electricity shortfall by more than half a percent of the National load.

Proposed strategy to mitigate UPS usage

To mitigate the effects of UPS usage it is important to encourage the use of solar and other alternative sources of energy. Solar panels generate power and can charge the UPSs and may also provide surplus electricity to the grid if net-metering is available. In Pakistan, sunshine averages 1700 to 2200 h per year with solar radiation of approximately 2000 kWh square meters per year (Ajayi, 2009; Anon., nd-b). The proposed strategy is to promote the installation and use of solar panels and solar energy power systems in the country, using financial support from both public and private sources. Through solar energy, we can ameliorate the energy crisis, but can also provide a cleaner source of electricity.

With some modifications, the UPSs currently in common use can be converted to use solar energy for charging batteries. Such conversion systems are already available in the market. Moreover, anecdotal evidence suggests that automotive batteries could also be used more efficiently with solar power due to slow charging. If the UPS inverter could be used with minimum changes and automotive batteries could be utilized with solar charging then such a solution, introduced on a mass scale, can be used to disconnect the UPS from the National Grid, thereby reducing energy wastage.

Conclusion and future work

The energy crisis in Pakistan is being aggravated by the fast growing and uncontrolled use of UPSs, which although a convenience for many at the household level, are causing damage to the country at the macro-level. The problem is that there is no short term solution to the energy wasted by inefficient UPSs. Therefore, there is a need to use alternate and green sources of energy to provide energy to consumers. The technological components of UPSs, such as inverters and batteries, can be charged by solar or wind systems. Innovative research is required to discover cost-effective ways to convert the UPS to alternate and green sources of energy. This will not only reduce the load on the National Grid but it will also add clean and renewable energy for the consumer (Javaid et al., 2011).

Acknowledgments

We would like to thank project "Climate Change Adaptation in Pakistan" funded by Canadian International Development Research Center (IDRC) Grant#106857 for funding this project. Many thanks to Dr. Adil Najam and Basharat Saeed for suggesting improvements in the manuscript. A special thanks to anonymous reviewers for their valued feedback on revising the paper.

References

Ahmed T, Ali S, Aliaga A, Arnold F, Ayub M, Bhatti M, et al. Pakistan demographic and health survey 1990/91. Islamabad: National Institute of Population Studies; 1992. p. 9–13.

Ajayi AB. A survey of solar energy power systems. 8th International Conference on Environment and Electrical Engineering; 2009. p. 10–3.

Amer M, Daim TU. Selection of renewable energy technologies for a developing county: a case of Pakistan. Energy Sustain Dev 2011;15(4):420–35. http://dx.doi.org/10.1016/j.esd.2011.09.001. [URL: http://www.sciencedirect.com/science/article/pii/S0973082611000767].

Anon. Survey:load-shedding in Pakistan. URL: http://rozee.pk, 2012.

Anon., nd-a Pakistanis ups usage during load shedding gilani poll/Gallup Pakistan. URL: http://www.gallup.com.pk/pollsshow.php?id=2014-01-28.

Anon., nd-b Solar radiation and positioning of solar panels in Pakistan. Technical report. URL: http://www.paksolarcells.com/solar-cells-positioning.asp?nodeid=43.

Barker S, Kalra S, Irwin D, Shenoy P. Empirical characterization and modeling of electrical loads in smart homes. Green Computing Conference (IGCC), 2013 International. IEEE; 2013. p. 1–10.

Dar MR, Azeem M, Ramzan M. Impact of energy consumption on pakistans economic growth. Int J Humanit Soc Sci Invent 2013;2(6):51–60.

Economic survey of pakistan. URL: http://www.finance.gov.pk/survey/chapters_15/Highlights.pdf, 2014-15.

Gurrero J, de Vicuna L, Uceda J. Uninterruptible power supply systems provide protection. IEEE Ind Electron Mag 2007;1(1):28–38. http://dx.doi.org/10.1109/MIE.2007.357184.

Department Research And Development The Lahore Chamber of Commerce. State of Electricity Sector in Pakistan; 2013h.

Javaid A, Hussain S, Maqsood A, Arshad Z, Arshad A, Idrees M. Electrical energy crisis in Pakistan and their possible solu-tions. Int J Basic Appl Sci IJBAS-IJENS 2011;11(05):38.

Moura P, Nuttall C, Harrison B, Jehle C, de Almeida A. Energy savings potential of uninterruptible power supplies in European Union. Energ Effic 2015:1–21.

Nair NKC, Garimella N. Battery energy storage systems: assessment for small-scale renewable energy integration. Energ Buildings 2010;42(11):2124–30. http://dx.doi.org/10.1016/j.enbuild.2010.07.002. [URL: http://www.sciencedirect.com/science/article/pii/S0378778810002185].

Nayyar ZA, Zaigham NA, Qadeer A. Assessment of present conventional and non-conventional energy scenario of Pakistan. Renew Sustain Energy Rev 2014;31:543–53. http://dx.doi.org/10.1016/j.rser.2013. 12.049. [URL: http://www.sciencedirect.com/science/article/pii/S1364032114000045].

Pasha HA, Saleem W. The impact and cost of power load shedding to domestic consumers. Pak Dev Rev 2013;52(4):355–73.