A Novel Approach Using Optimization Algorithm For Economic Dispatch Of DG Sources In Nano Grids

By

Abdul Kashif Janjua

Reg # NUST201463509MECES64114F

Session 2014-16

Supervised by

Prof. Dr. Muhammad Bilal Khan

A Thesis Submitted to the U.S.-Pakistan Center for Advanced Studies in Energy in partial fulfilment of the requirements for the degree of

MASTERS of SCIENCE in

ENERGY SYSTEMS ENGINEERING

U.S.-Pakistan Center for Advanced Studies in Energy (USPCAS)

National University of Sciences and Technology (NUST)

H-12, Islamabad 44000, Pakistan

February 2017

THESIS ACCEPTANCE CERTIFICATE

Certified that final copy of MS/MPhil thesis written by Mr ABDUL KASHIF JANJUA , (Registration No. NUST201463509MECES64114F of USPCAS-E has been vetted by undersigned, found complete in all respects as per NUST Statues/Regulations, is free of plagiarism, errors, and mistakes and is accepted as partial fulfilment for award of MS/MPhil degree. It is further certified that necessary amendments as pointed out by GEC members of the scholar have also been incorporated in the said thesis.

Signature: ______________________________

Name of Supervisor ______Dr . M. Bilal Khan

Date: ________________________

Signature (HoD): ________________________

Date: ____________________________________

Signature (Dean/Principal): __________________

Date: ____________________________________

Certificate

This is to certify that work in this thesis has been carried out by **Mr. Abdul Kashif Janjua** and completed under my supervision from USPCAS-E, National University of Sciences and Technology, H-12, Islamabad, Pakistan.

Supervisor: ______________

Dr. Muhamad Bilal Khan
USPCAS-E
NUST, Islamabad

GEC member # 1: ______________

Dr. Majid Ali
USPCAS-E
NUST, Islamabad

GEC member # 2: ______________

Akif Zia Khan
USPCAS-E
NUST, Islamabad

GEC member # 3: ______________

Atiq Ur Rehman
Faculty of electrical engineering
AIR UNIVERSITY, Islamabad

HoD-CES ______________

Dr. Zuhair S Khan
USPCAS-E
NUST, Islamabad

Principal/ Dean ______________

Dr. M. Bilal Khan
USPCAS-E

Dedicated to my beloved prophet

Muhammad PBUH (وسلم عليه الله صلى)

And

his Ummah

Abstract

This thesis presents an overview of the architecture for smart Nano grids, integration of various diversified distributed generation technologies in Nano grids at small community level and different policies governing its implementation. The work also reviews the current energy scenario of Pakistan with emphasis on the need of setting up small scale Nano grids with integration of V2G technology for decentralization and deregulation of the currently wrecked power sector of Pakistan. Various load profiles along with load shedding schedules have been tested under the simulation of the presented Nano grid architecture. The promising results obtained after running the simulation testify the fact that integration of vehicles at small community level can provide a viable solution to eradicate the menace of energy crisis by offering peak shaving and demand side management benefits.

Key Words: *Smart Grids, Nano grids, Smart Nano Grid architecture, Photovoltaic systems, Vehicle to grid (V2G) Technology*

Table of Contents

Table of Figures

List of Tables

Chapter # 1 :Introduction

1.1 Growing demands and need of grids

The Advancements and innovations[1] in smart grids are making energy more economically accessible to users with least faults and high reliability. The technological advancements have been in various domains of smart grids namely information and communication technologies (ICT), power conditioning, power fault analysis, distribution automation, online monitoring and fault diagnosis, and self-healing networks. The essence of a smart grid is in the flexibility to manage huge power sources among very non uniformly distributed load all over a specific area[2].Every developing country's energy needs are increasing day by day and to meet the requirement various renewables and conventional means are being deployed. A worse situation is being faced in Pakistan where the current shortfall of electricity is 22%-50% in winters and summers respectively of the total requirement. This demands immediate action to be taken among other various techniques conservation of power and integration of renewables is an effective way of reducing the shortfall very quickly.

The nature of renewable source in a country is determined by the geographical location and the sources available to the country but solar energy is available to most of the countries under various energy intensities. Pakistan is one of the world's most suitable locations for the installation of solar energy harvesters namely solar Photovoltaic(PV) panels while the potential of hydro power and wind power are also very promising at various locations of Pakistan[3].

Integration of these renewables in national grid is also very critical and new polices have been issued by the government for completing such projects without any glitch. Since the integration of such resources into national grid is a modern way to use the energy, new and efficient ways of doing so are becoming more common now among which Distributed power generation is worth mentioning which provides power on distribution scale thus reducing the line losses in transmission lines immensely and allowing decentralization of the power grid.

Local grids serving a localized community such as micro grids and Nano grids which may or may not be connected to national grid are also among the doable solution for energy deprived countries where the people can contribute towards the national energy needs themselves rather than waiting for the government .In this case government has to take the lead by providing incentives to the investors and devising such policies which promote setting up of small scale Nano grids meeting the localized indigenous energy demands and relieving the stress on the national grid. This section presents an overview of smart Nano grid as a solution to country's energy needs.

1.2 Energy scenario in Pakistan

Primarily the research was based upon generic power systems but with the literature review the refinement of objective forced the direction of research to be cantered upon the current power scenario of Pakistan and how the power sector of country Pakistan be stabilized with the involvement of distributed generation systems. The country is abundantly rich with renewable resources present in various form across the stretch of the country. the current economic situation of the government and the law and order situation forces people to rely less on the authorizations thus the hole for a unique power system is created which not only considers the power resources indigenously deployed by the users or customers but also integrates the grid electricity and ultimately managing the power low of the whole system in various homes and loads is economically in the under developed country like Pakistan.

The making of such topologies and management systems would not only enhance the reliability of the power sector in the country but it shall also improve the living standards of the people. Subsequently the installation of such distributed generation sources shall be a major support towards the national grid as the transmission system of the country lacks the power to transfer the current power demand to the consumers. likewise, if for the distributed systems.

The main objective of the whole research everywhere in the world is to increase the comfort of living of people. My research is dedicated towards the people of my country.

1.3 Resources

Pakistan despite having huge potential of various renewables mainly depends on the imported oil for the energy sector. Despite the import of this oil the electricity has a short fall of approximately five to eight thousand MW which is a huge difference which can be up to 22% of the maximum demand. This demand is around 25000 MW per year[4]. The demand of 22% is for 2014 which is less than the percentage shortfall in year 2008 which was 37%. The shortfall in the peak hours even go up to 50% in summer season plunging the country in long hours of darkness and causing a gigantic loss to the national exchequer. This demand is projected to increase in the future as the numbers of users are continuously increasing with the growing population of the country[5]. As the users have increased form 7.9 million to 19.9 million from year 1990 to year 2010[6], the demand in energy is predicted to increase to 163000MW by 2030 which has be to planned and long term energy generation goals have to be made According to Robert Hathways and Michell Kugelmn of Pakistan oxford university press, the energy short fall shall be around 32000 MW in 2030 if the development in energy generation systems is on the same pace as it was in the last decade[7]

Aforementioned stats stand valid only if the electricity generation is expanded at the same pace as it was done during previous two decades but the recent policies and priorities of government have changed and now energy production has gained extreme importance in the country. Water and energy are the most invested upon areas in the country with international aid from multiple donors also being poured in the same domains. Now new policies for the renewable resources are being made and implemented in the country which the country holds tremendous potential [5].

The potential of major renewable resources available in Pakistan is mentioned in Table 1-1

Table 1-1 Power potential of various renewables in Pakistan [8]

Source	Energy available (GW)
Solar PV	1000

Hydro power	51700
Wind	3000
Biogas	5700

Where the present power generation from the thermal and hydel projects has been summarized in the following tables

Table 1-2 :Power production by private sector in Pakistan[9]

Station	Location	Capacity (MW)
Kot Addu Power Company Limited	Kot Addu,Muzaffar Garh, Punjab	1,600
Hubco Narowal Power Plant	Narowal,Punjab	225
Bin Qasim Power Plant I	Karachi,Sindh	1,260
Bin Qasim Power Plant II	Karachi,Sindh	560
Jamshoro Power Station	Jamshoro District, Sindh	850
Lalpir Power Limited	,Muzaffargarh,Punjab	362
Altern Energy Limited	Fateh Jang,Punjab	29
Atlas Power Limited	Sheikhupura,Punjab	225
Attock Gen Limited	Rawalpindi,Punjab	165
Fauji Kabirwala Power Company	Kabirwala,Punjab	157

Nishat Power Limited	Lahore,Punjab	200
Nishat Chunian Limited	Lahore,Punjab	200
Sapphire Electric Company Limited	Muridke,Sheikhupura District,Punjab	234
Saba Power Company Limited	Farooqabad,Sheikhupura,Punjab	125
Southern Electric Power Company Limited	Raiwind,Lahore	136
Tapal Energy Limited	Karachi,Sindh	126
Japan Power Generation (Pvt) Limited	Raiwind,Punjab	135
Kohinoor Energy Limited	Lahore,Punjab	131
Sitara Energy Limited	Jaranwala,Faisalabad, Punjab	85
Saif Power Limited	Sahiwal,Punjab	225

The hydel and nuclear power plants are as follows

Table 1-3Power production of various hydel sources in Pakistan [9]

Dam	Power MW
Duber Khwar Dam	130
Jabban	22
Gomal zam dam	17
Khankhwar	72
Jagran	30
Chitral	1
Renala	1
Kurram Garhi	4
Nandi pur	14
Tarbela	3578
Mangla	1000
Ghazi-Barotha	1450
Warsak	243
Nuclear power Plants	
Chashma	184
Dargai	20
Rasul	22
Shadi-waal	13.5

Many power plants are proposed and under construction here is a list of the power plants in such a state

Table 1-4 Power proposed power projects

Plant	Capacity	type	place
Thar power plant	100MW	thermal	Tharparkar,islamkot,sindh
Grange holding power plant	163MW	thermal	Arifwala punjab
Jhang RLNG power project	1230MW	LNG	Haveli bahadur shahmjahang
Balloki kasur RLNG based power project	1000-1200MW	LNG	Kasur
Jamshoro coal power project	600MW	coal	Jamshoro sindh
k-electric coal power plant	660MW	coal	Karachi sindh
Thar power plant	660MW	Thermal	Tharparkar,Sindh
Thar coal power plant	1320MW	Coal	Tharparkar
Muzaffargarh sugarcane husk power project	120MW	husk	Muzaffargarh, Sindh
Maple leaf power	40MW	coal	Mianwali
Neelum-jhelum power plant	969MW	Hydal	Azad jamu kashimir
Golen gol hydro power	106MW	Hydal	Chitral
Patrind hydro	147MW	Hydal	Abbottabad,muzafarabad
Bhasha dam	4500MW	Hydal	Chilas gilgit
Keyal hydro power	128MW	Hydal	Kohistan KPK

Dasu dam	4320MW	Hydal	Dassu KPK
Karot hydro power	720MW	Hydal	Rawalpindi district
SK hydro power	840MW	Hydal	Kaghan velly mansehra

The resultant energy mix of power by sectors is as follows

Table 1-5 Power mix of various sectors in Pakistan [10]

Source	Percentage contribution
Thermal (GENCOs)	19.4
Hydel(WAPDA)	30.1
Nuclear(PAEC)	3.1
IPPs(thermal)	36.8
K-electric(thermal)	8.6
Rental(thermal)	2

1.4 Distributed generation in Pakistan

The Distributed generation sources are the most diversified combination of electricity generation for any area[11].Mostly the term distributed generation (DG) is defined in different perspectives and in various ways as in literature various authorities have defined it according to their own assessment and focus of research. Distributed generation sources are used to provide active power for the distributive network directly. This ensures many advantages such as the reduction in power losses, better economic dispatch operation, area specific network generation, reduction in transmission losses, high reliability, improved power quality, dispersed energy production, less carbon foot prints and improved power capacity. Despite of some of the demerits of deploying DG sources such as the bidirectional power flow causes reduction in voltage regulation and causes voltage unbalance in the system, sufficient headway has been made in this technology and such systems can be easily implemented in the developing countries like Pakistan.

With the advent of distributed generation sources, more penetration of renewable energy sources at distribution network level has become possible making it easy for the network operator to perform monitoring, regulation and corrective actions. Power produced by renewables is intermittent and dependent upon meteorological conditions. Since these conditions vary along the geographic terrain of a country therefore geographic dispersion of renewables is preferred for maximum utilization of different diversified renewable sources This deployment scheme of renewables allow near uniform energy to be fed to the power grid. Therefore, energy production from renewables and geographically distributing them across the grid can help to increase the reliability of the renewables and overcome their intermittency issue. In such a configuration, there will be no need to raise the bar of system spinning reserves requirement

Pakistan has been bestowed by Mother Nature with a prodigious weather and a rich geography. From sky touching and the world’s tallest mountain ranges of Himalaya, Karakoram and Hindu Kush in north to the 1046 km coastline in the south and widespread stretches of scorching desert along eastern border with India and

Western border with Iran, Pakistan experiences an extremely diverse weather simultaneously throughout the country posing an ideal condition for the installation of different diversified distributed renewable source. Some of such DG sources and their potential location in Pakistan are presented in table 1-6

Table 1-6 Area dependent renewable energy potential of various places [6]

Source	Location
Micro Hydro	Gilgit Baltistan, KPK, Azad Jammu And Kashmir
Wind Turbines	Gharo, Jamphir, Ketty Bandar, Karachi Up To Hyderabad, Islamabad And Some Areas Of KPK
PV	Bahawalpur, Thar And Cholliston Deserts In Punjab And Sindh While Quetta And Peshawar In KPK And Baluchistan
Solar Thermal	Bahawalpur Thar And Cholistan Deserts In Punjab And Sindh
Biomass Based Generation	Central Punjab And Upper Sindh
Fuel Cell Based Generation	Areas With High Hydrogen Production Potential Like Through Thar Coal

The current scenario of energy harnessing from diversified DG sources in Pakistan is getting better with each passing day. Micro hydro plants have been installed in KPK and Gilgit Baltistan, producing total of more than 8 Mw[12]. Similarly, bio gas installations are producing 1800m^3/day. Incumbent government has set the ambitious targets of increasing the production of these sources by approximately 100 % till 2020[13]. Similarly, substantial investment is being done in the solar PV sector such as Quaid e Azam solar power park with a cost of 131 million dollars and a capacity of 100 MW[14].

Energy harnessing from these diversified distributed renewable sources is beneficial if these sources are integrated with the national grid tackling their intermittency issue. However, in the event of islanding operation such as in Nano grids, relying on a single source of renewable energy poses a serious threat to system security and integrity as simultaneous existence of various resources in a small community is only coincidental. [15].As clear from the above table that every source has great potential in the country but the problems of energy reliability are being introduced in the case of small targeted area[16].

Introduction of energy storage systems can help to increase the reliability of the system at a certain cost making system more robust to contingencies. If such infrastructure is implemented at various locations on small scale community level, the power sector of the country can get a great lift to fight the energy crisis. Such small setups of community scale come in the category of Nano or micro grids. This section gives a brief overview about the introduction and architecture of a Nano grid using DG sources in Pakistan.

1.5 Government policies for distributed generation

The escalating energy demand of the country is forcing the government to make the policies more flexible, attractive and favorable for the foreign investors and for the local bodies to invest in this lucrative area as the same is reflected by the efforts of incumbent government. During the previous decade there was no focus on renewable resources Feed in tariff was very time consuming and long licensing procedures made it difficult for the renewables to be incorporated into the government systems[17].

Pakistan’s energy sector has always faced issues regarding to policy. No initiative have been taken on formulation of a detailed and a combined energy policy, normally ad-hoc based policies and bills have been passed in parliament and no concrete single policy has been formed .It is clear from the discussion done in this section that policy has a very close relationship with technology implementation and cost effectiveness of new technologies[18][19]. Some extremely suffering technologies are shale gas and coal mining technologies. Pakistan’s energy policy over the span of some decades is as follows.

In 1994 the first framework for the private power generation was produced and implemented to meet with the increasing energy deficient. An improvement was made after approximately one decade in 2002 which encouraged the IPPS to be made and produced giving the major boost to power production. Rental power plants and thermal power plants were deployed as a result of this policy change in next five years. First proper framework for the new IPPs was provided by PEPCO in 2006 which covered the renewable energy production to a small extent. This was the first policy which paved the way for the renewable energy investment. This was elaborated in year 2009 giving more detail to the renewables.

The recent power policy of 2013 has a vision of affordable and efficient energy production and utilization making it very clear that the government is encouraging people and making such policies to ensure the energy conservation and affordability of energy as well as trying to cope up with the energy deficit in the country. On the other hand, the scope of production, taken into account from 2008 onwards is more flexible than only targeting the IPPs (independent power plants) but now it is coming to captive cum grid spill power projects on small scale and captive power projects for self-use and dedicated use. Recently in 2014 net metering policy was introduced in the country[13].

Despite the efforts being put into the policy making and giving fringe benefits to the people a certain lag is being observed in the politics where the policy makers have failed to do successful lobbying in the parliament and which results into countless discussions over various bills tabled in the parliament resulting in negative impact upon the energy sector of the country. No policies for implementation of Micro/Smart Grids have been introduced in Pakistan although huge quantum of work was done during the USAID funded Power Distribution Project (PDP) started in 2010 to implement some aspects of the smart grids at distribution company (DISCO) levels by installing smart energy meters, implementing substation automation and retrofitting of different thermal energy units. PDP project was more focused on the capacity building of human resource and increasing the utilization of existing infrastructure. Load management has been highly improved from power distribution project (PDP). Major work has been done with all nine distribution companies; 119MW of power has been secured by capacitive bank installation in grids for power factor improvement which has saved approximately 133 million us dollar to the government. More than 50,000 smart meters have been installed in the target locations at substation level. However, fully functional pilot project of implementing Smart Grid architecture in its true letter and spirit for a specific region as of Islamabad is still seen as a distant dream[20].

Chapter # 2 :Smart Nano Grids

2.1 Introduction

A small scale grid which has been implemented at community level to cater the local needs of energy production, distribution and consumption is called the Nano grid[21]. A very recent definition to it is that Nano grid provides an infrastructure for power and information communication technologies where at least one power sink and one power source should exist with availability of power gateway to the outside electric companies while storage can or cannot exist in the grid. Some researchers also define the Nano grids as aggregation and interconnection of various generators having total production around 20kW to provide power in area spread of 5 km radius of a central point.

2.2 Architecture

A smart grid has a conventional grid [22] architecture with some advancements like balancing of demand and supply on various time scales, forecasting of power production and loads in various time scales. This is only possible by augmenting some extra functionality present in the existing system which mainly base upon monitoring data management and analysis of power flow of the grid at various predetermined points[23] It involves multiple layer of abstraction from the physical to communication to data mining and data analysis layer and ultimately to control layer[24].

Similar grid architecture is implemented on a Nano grid scale. The difference is only in the size of the system which puts a constraint on funds and hardware usage on the system so more sophisticated system is required for Nano grids which are equally or [2]nominally less efficient than that of the national grids but extremely responsive to various parameters and resultantly produce same results as in the micro or national grids in terms of power and cost efficiency.Hydrogen gas production by dark fermentation.

2.3 DG sources for Nano grids

The scale of the Nano grids restricts the costs and it also gives us various advantages as the area to which the grid is to be implemented is extremely small and can be easily monitored controlled and protected through various networking protocols. It reduces the usage of extremely fast communication devices which add up a huge amount to the grids system. DG sources in Nano grids

The installation of DG sources in Nano grids is dependent on the geography and meteorological conditions moreover it also depends upon the vehicle to grid and vehicle to house (V2G and V2H) technologies. There are various energy storage systems that are already present around us but are not being used efficiently. Some of these are the overhead water storage systems available in every community and the hybrid electric vehicles (HEV) battery banks. Such energy storage devices have recently been pondered upon and people are now exploiting these resources.

Resultantly new energy storage systems are connected to the grid. These particular energy storage systems are very small but now available in form of hybrid and electric vehicles When power from Electric Vehicles (EV) or Hybrid Electric Vehicles (HEV) is fed to the home energy management system or to the grid they are formally known as vehicle to grid (V2G) and (V2H) vehicle to house technologies[25].

V2G and V2H technologies are an efficient use of available redundant energy storages. On the other hand, the use of these energy storages also requires extreme care in handling and coordination with other available vehicles in the community. The prediction of future energy productions, available power and loads all must be available and optimally coordinated with the grid controller else transport from the vehicle will be compromised.

Algorithms are being made for the efficient extraction and insertion of energy in electric banks of the vehicles when plugged into the grid outlet. Both technologies require basic electric devices for the electricity conversion .Inverters, converters, DC regulators and frequency regulators are necessary aforementioned technology[25].

The quality of the technology is that it can behave as electric load when surplus power is available and a generator when the power is limited due to unavailability of any DG source in the grid system.

DG sources have been recommended by various studies for different countries having high DG source potential. Some major reports were made are as follows

Table 2-1 Dg sources proposed in various countries

Country	Sources	Reference
UK	Onshore wind, offshore, hydro, solar PV, wave and tidal, bioenergy	[26]
USA (Caribbean and Latin America)	Hydropower, wind power, solar PV, biomass, Geothermal, CSP	[27]
USA rural utility service at duck valley	Wind power , solar power(PV,CSP),	[28]
Saudi Arabia	Solar PV	[29]
Iran	Geo thermal, wind power, solar PV coal oil and gas	[30]
Brazil	Solar PV	[31]
USA Georgia southern university	Solar PV, wind, bio power, fuel cell, hydroelectric.	[32]

The traditional factors associated with the batteries act as constraints for the behavior of loads and generators namely the charge and discharge rates and the number of cycles. These parameters depend entirely on the type of battery[33]. Despite the constraints the technology is now being used efficiently in homes.

The Nano grids being a small scale grid can easily use the energy storage units available in the vehicles. Main objectives of this integration are to provide the power continuously to the loads and bear the high gradient of load curves.

2.4 Nano grids with V2G in Pakistan

This section gives a perspective of implementation of Nano grids in Pakistan. The previous discussion has strongly proved that the energy sector is lagging and extreme short fall of electricity has to be seen in the country which forces the government and the local population to take preventive measures and build the energy production facilities. Large power production facilities being out of the scope of local community and social circles of the country make the small scale Nano grids and micro grids implementation for the local community very attractive. Here there are various driving factors for the people and small investors to focus upon the Nano grids as they provide a very bright future for the energy conservation of the country. The next sections of the thesis present the impact of such system involving the V2G technology and solar technology at Nano Scale level to offer ancillary services to relieve the burden from overstressed national grid.

The immature technology and non-availability of electric vehicles forces the users to be unable to experience the fruits of V2G technology fully but sale of cars in Pakistan is on upward trend due to the introduction of the leasing by banks on nominal interest thus increases the possibility of hybrid cars quick introduction in the country. According to the PAMA (Pakistan automotive association), the sales of cars above 1300cc was 121816 in year 2014 Most of the cars in the country are not even hybrid but the prospect still remains. Toyota Prius is the car which is normally seen on the roads. The total annual car sale is given in the figure on the next page

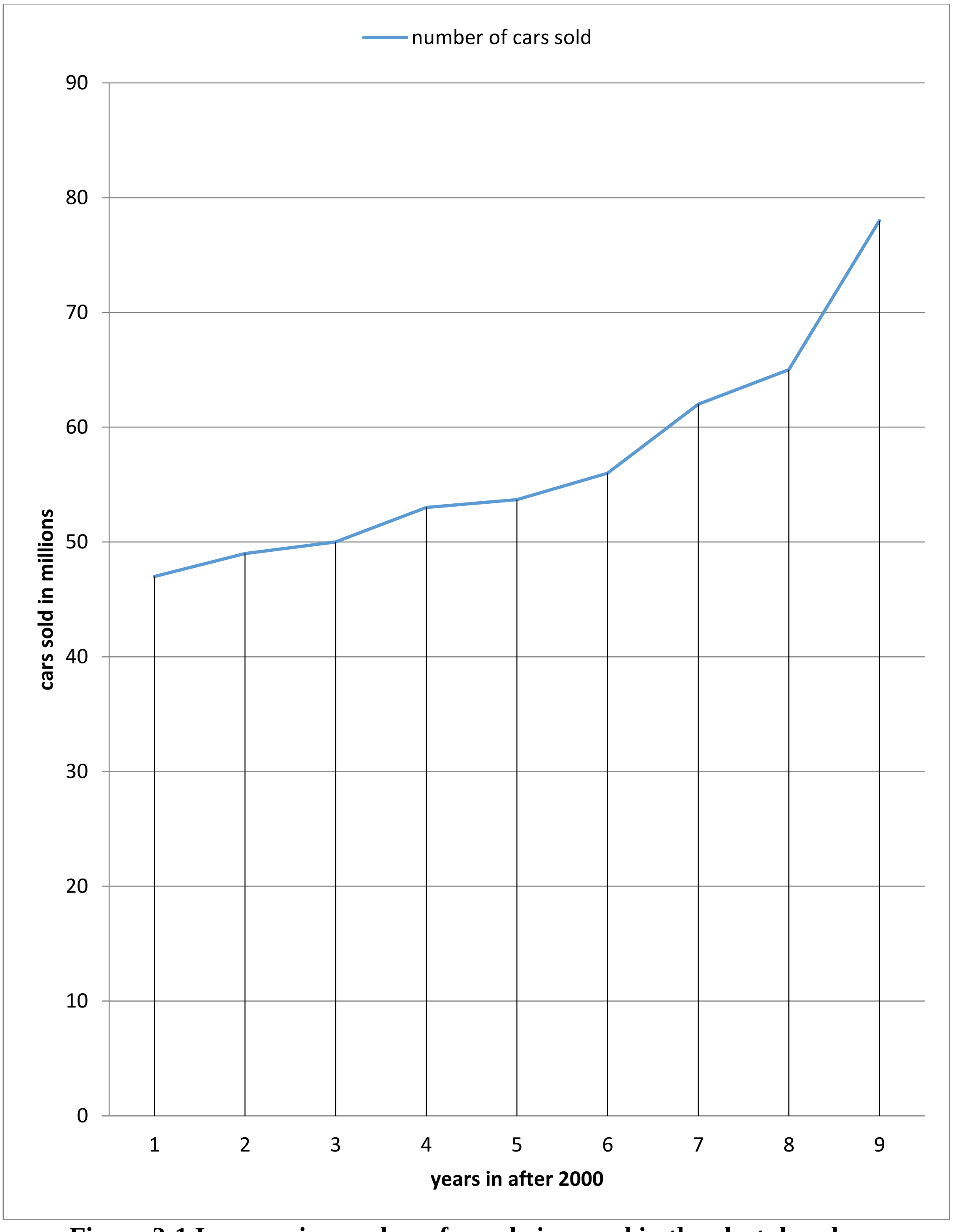


Figure 2-1 Increase in number of cars being used in the last decade

The above graph indicates that the number of new cars being sold in the country has an increasing trend and the gradient is increasing with the time. This section gives a brief analysis on the prospects of the implementation of V2G technology in the country and how it can help in the energy scenario explained above for the economic development of the country.

2.5 Behavioural model of Nano grids

A mathematical model of the grid has been implanted in the work done for the sake of testing V2G technologies to help in the economic dispatch through various sources inside the Nano grid namely solar grid battery and vehicular battery. The model restricts its self to the power and costs of electricity and does not deal with the fault analysis and power quality in the grid. Despite these power sources it can be used to increase the power reliability and power quality in the system.

The model uses the commercially available converters and inverters in itself, moreover it only uses the power and cost efficiencies of the electronics modelled. Thus a very reliable data in terms of power and cost can be found in the results.

The architecture of the grid has been laid as illustrated in the figure

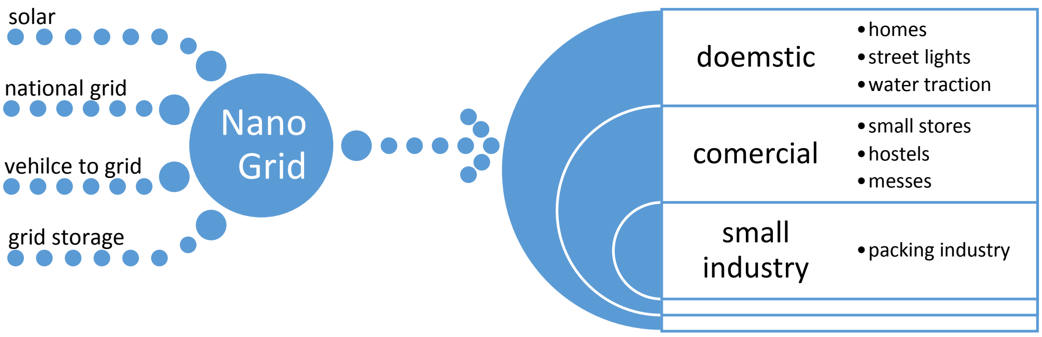


Figure 2-2: Nano gird

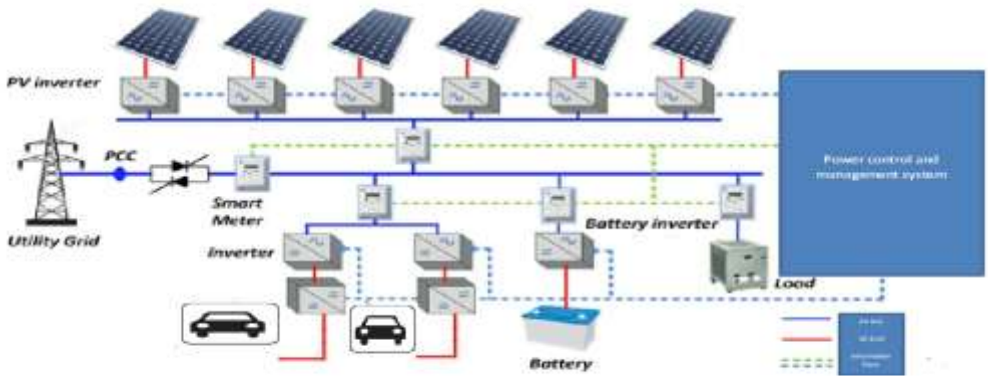


Figure 2-3 :An overview of Nano grid scope and architecture

The above diagrams shows the structure of the Nano grid[34]. where the load may or may not be depending on the characteristics of the Nano grid. As clear from the basic diagram, the grids major users may be of any type but the total power cap should be small. The working models of such grids are being developed in Bangladesh, India and various other countries. Model implemented for the testing purpose of this thesis is presented in following

The constants used in the model are presented

Table 2-2: specifications of grid simulations

Specification	Value
Annual sun shine hours of Islamabad	3090 Hrs.
Total solar capacity	3KW
Initial cost of solar system (panels plus wiring)	200,000RS
Solar payback time period	7 years
Annual Operation and maintenance cost	10000Rs
Life of inverter used	4 years
Efficiency of solar panel	17.4%
Cost of IESCO unit	14.5 , Rs
	18Rs(7pm to 11 pm)
Voltage of grid battery	12v
Voltage of vehicle battery	12v
Cost of grid battery	10000 Rs
Cost of vehicle battery	3000RS
Number of cycle grid battery	400 cycles
Number of cycles vehicle battery	300 cycles
Ampere hours of grid battery	200amph
Ampere hours of vehicle battery	80amph
Depth of discharge of grid battery	0.4
Depth of discharge of vehicle battery	0.6

The annual sunshine hours of Islamabad were calculated from the tables provided by met department of Pakistan The data for solar power has been taken from the solar intensity falling in Islamabad from metronome. The cost of the solar panels, inverter battery including specifications, have been taken from local venders 'Nizam solar systems' offering Rs. 110 per watt cost of Yingli solar panels. IESCO unit was taken from the bills of IESCO. The model has been made to be a run time problem solver using the current values on load vector and the solar intensity vector to produce the power output vector for the grid thus giving the economic dispatch results over horizon of 24 hours. The model works on a priority based power transfer to the load in the grid. The conditions are predetermined according to fig 4 for the power transfer to the loads.

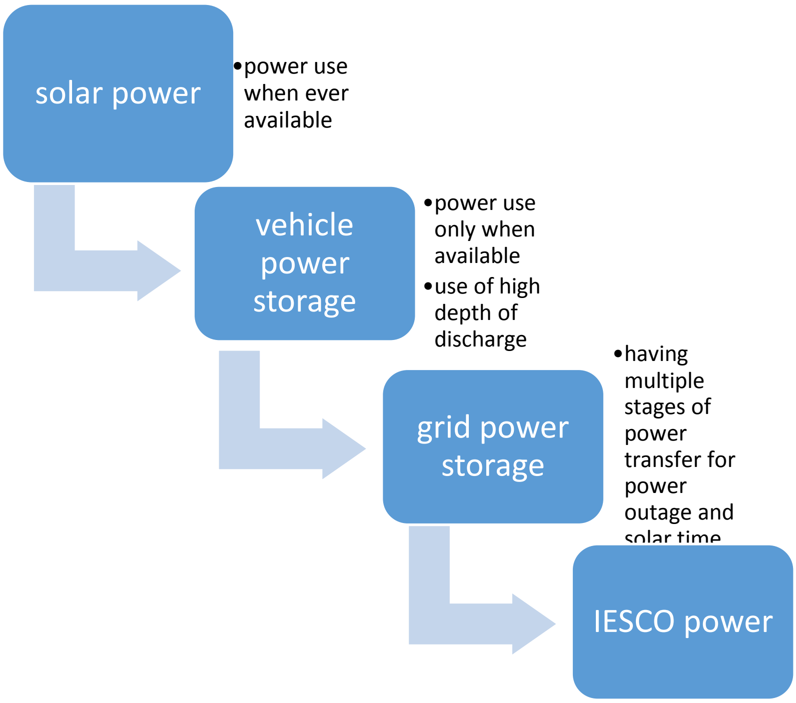


Figure 2-4 an overview of Nano grid implementation

The cost calculation of the IESCO power is taken from the power sources but the cost per unit being provided through the other sources is calculated through following mathematical equations

Cost of solar power

$$cost\ per\ unit_{solar} = \frac{\left(cost_{solar_{initial}} + (oem_{solar}.* lifetimesolar)\right)}{365 * lifetimesolar * capcity_{total}} \qquad (1)$$

$$cost\ per\ unit\ battery = \left(\frac{cost_{bat_{grid}}}{\left(number_{ofcycle_{grid}}\right) * amph_{grid} * voltage_{batt_{grid}}}\right) * 1000 \qquad (2)$$

Where 1.18 is the power loss factor in the charging and recharging in the battery

Cost of vehicular battery is determined by the same formulae like the one used for grid battery storage ***The charging and discharging of batteries***

$$battery_{charge_x} = battery_{charge_{x-1}} - \left(\frac{power_{dilivered}}{amph_x * \frac{voltage_{batt_x}}{1000}}\right) \qquad (3)$$

Summary: The chapter discuses the basic way in which the power is being routed in the devices . The technical details of such a grid and the commercial technology available in Pakistan enable us to use it for the implementation of the idea that is being presented in the thesis

Chapter # 3 :Data acquisition and load curves

An extensive survey was held over a total of 384 respondents to generalize the dataset over the city of Islamabad it was then curve fitted over the data of feeders in Islamabad after dividing it on the number of homes attached to those feeders to make the data more reliable and accurate. The devices were kept inquired upon from the respondents are kettle, oven, blender, fridge, water cooler, iron, air conditioner, sound system, fan, geyser, water pump, washing machine, lights and computer

Following came out to be the overall results for the average number of devices per home present in these respondents

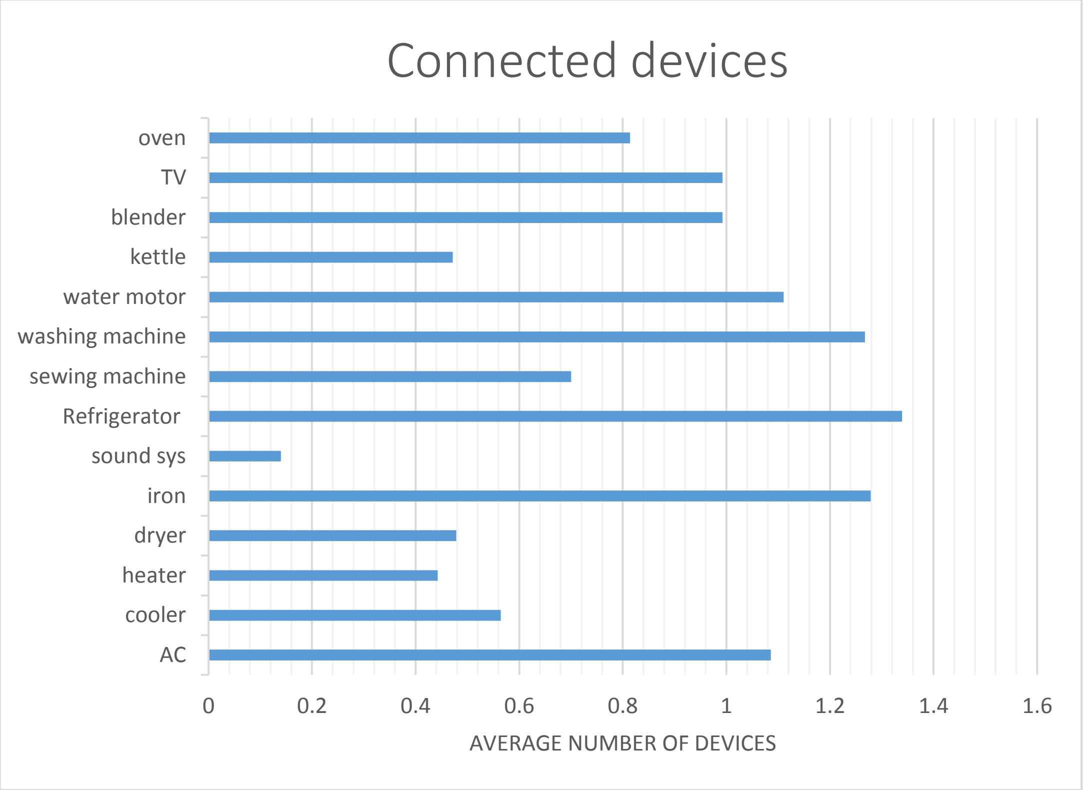


Figure 3-1 Average connected devices

The data was then used to develop load curves for an overall 3 levels of ease of the people over three different seasons summer winter and moderate weather. The stats for each device are as follows in the following graphs.

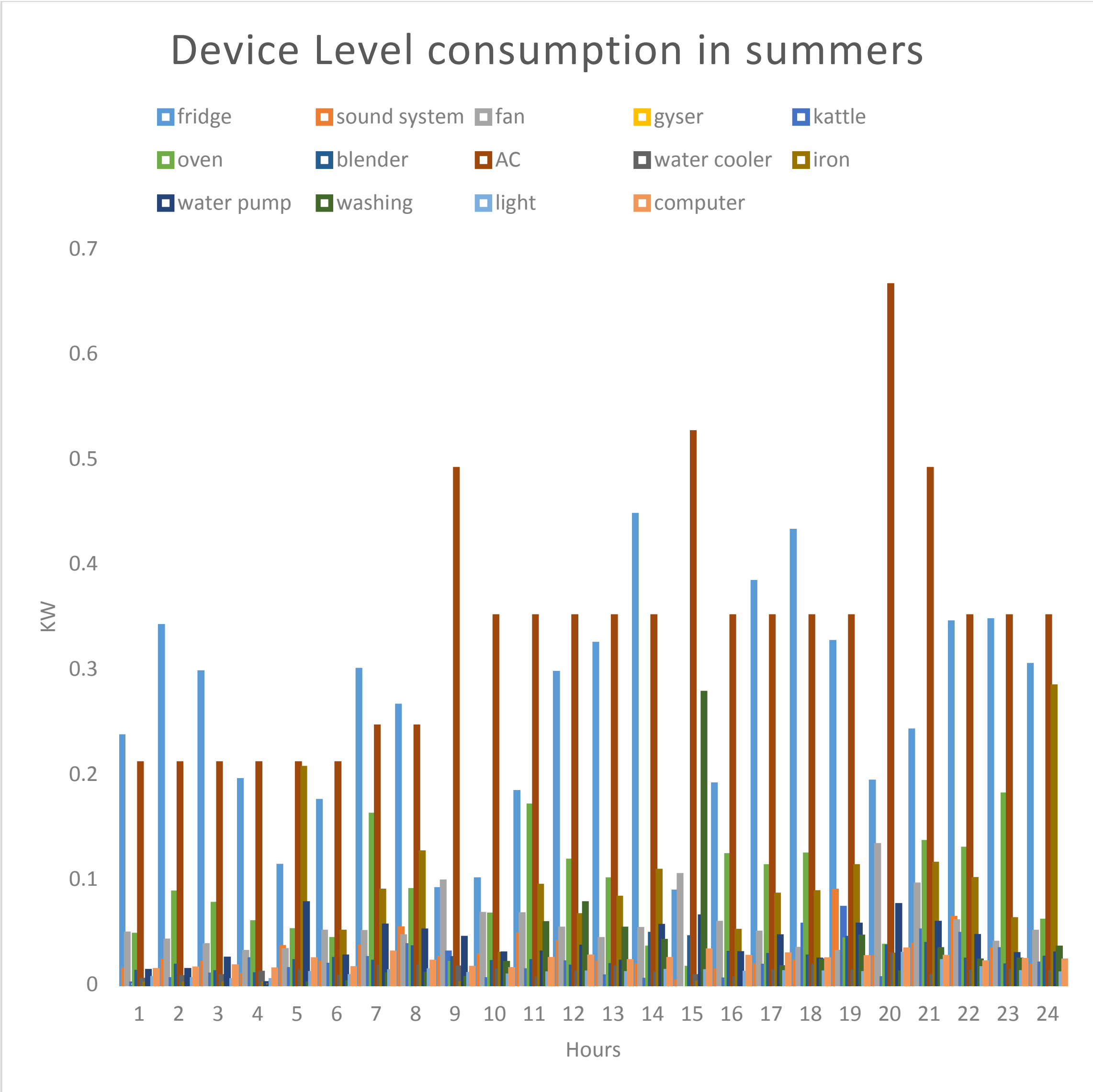


Figure 3-2 device level load curve in summers

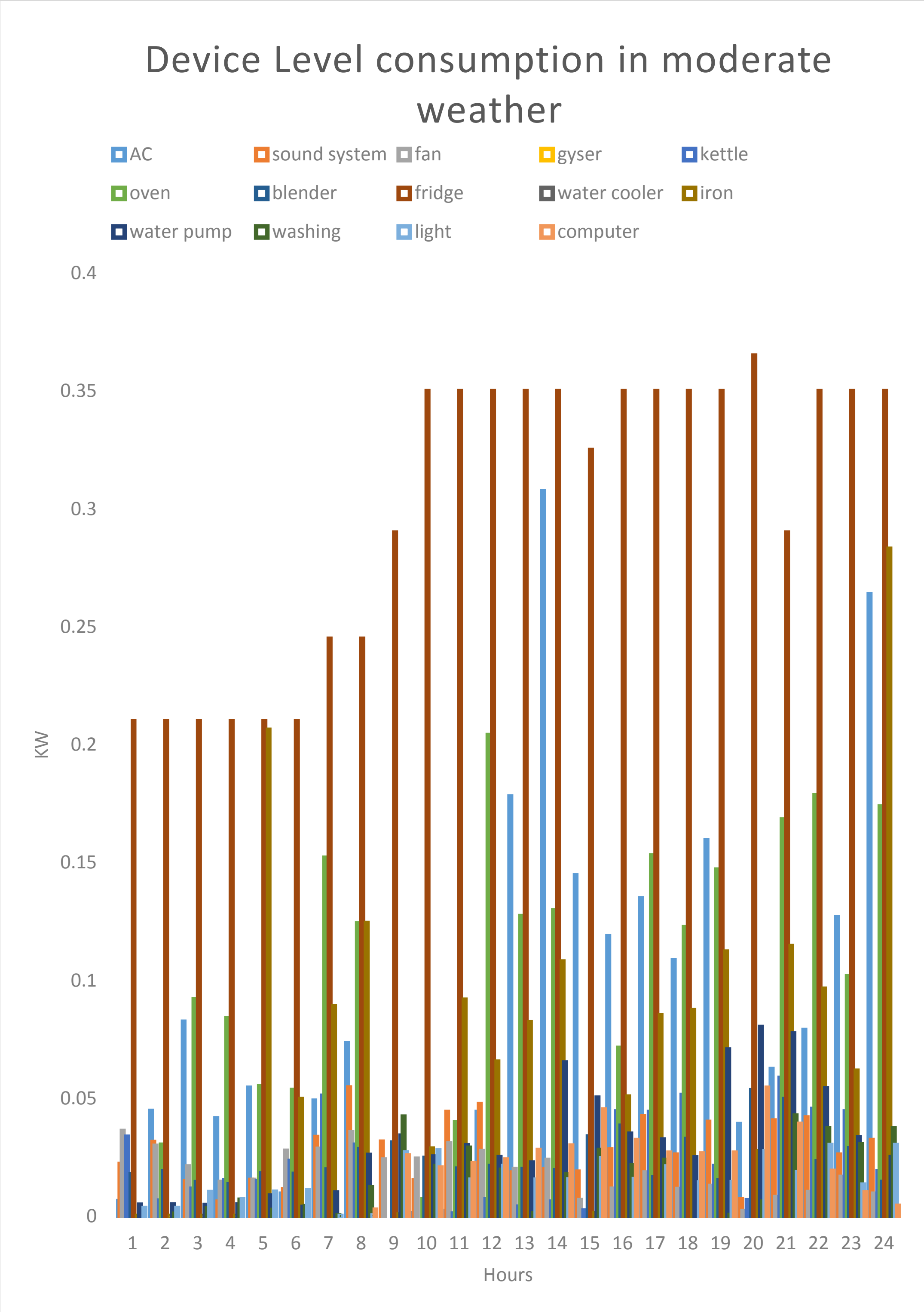


Figure 3-3 :Device level load curve in moderate weather

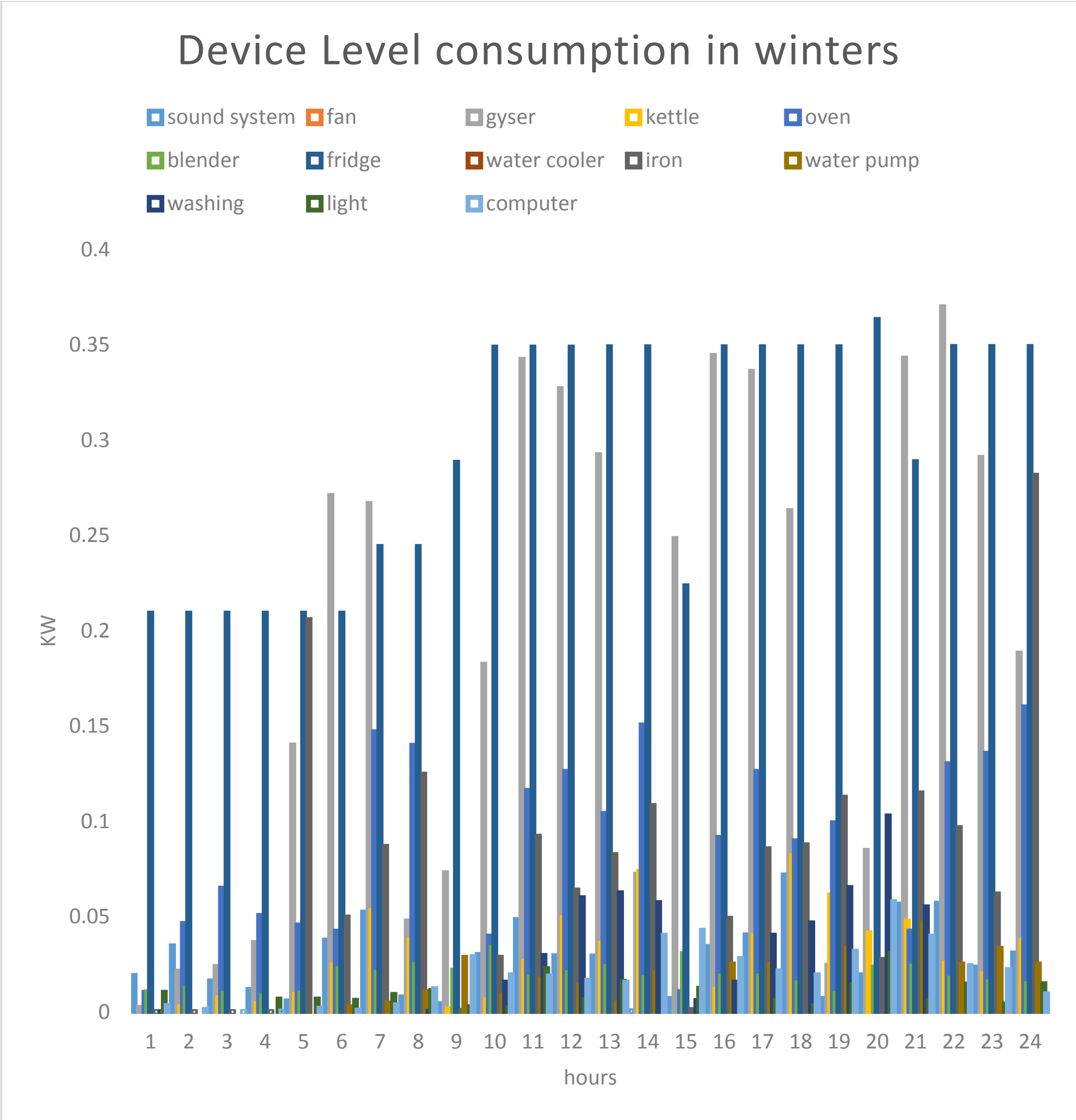


Figure 3-4: device level load curve in winters

The units of ease were surveyed and divided into full load UPS connected load (fans lights and computers mainly) and a load of only the lights of the connected loads being shown in the following clock charts showing the power in KW being consumed

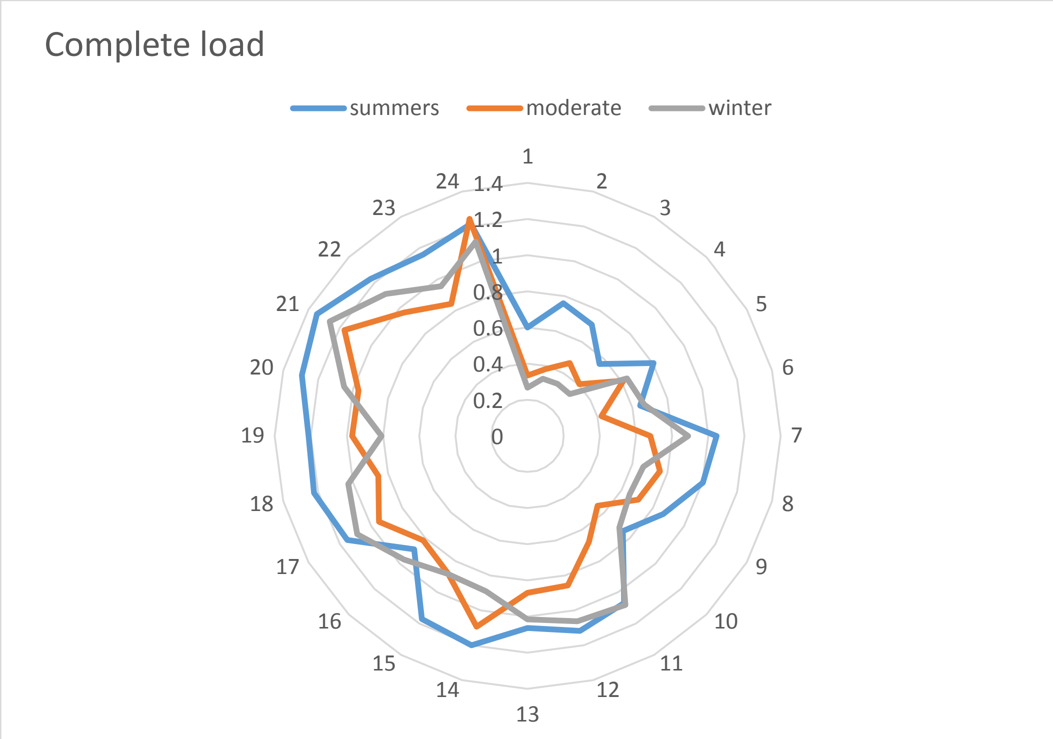


Figure 3-5: full load pattern

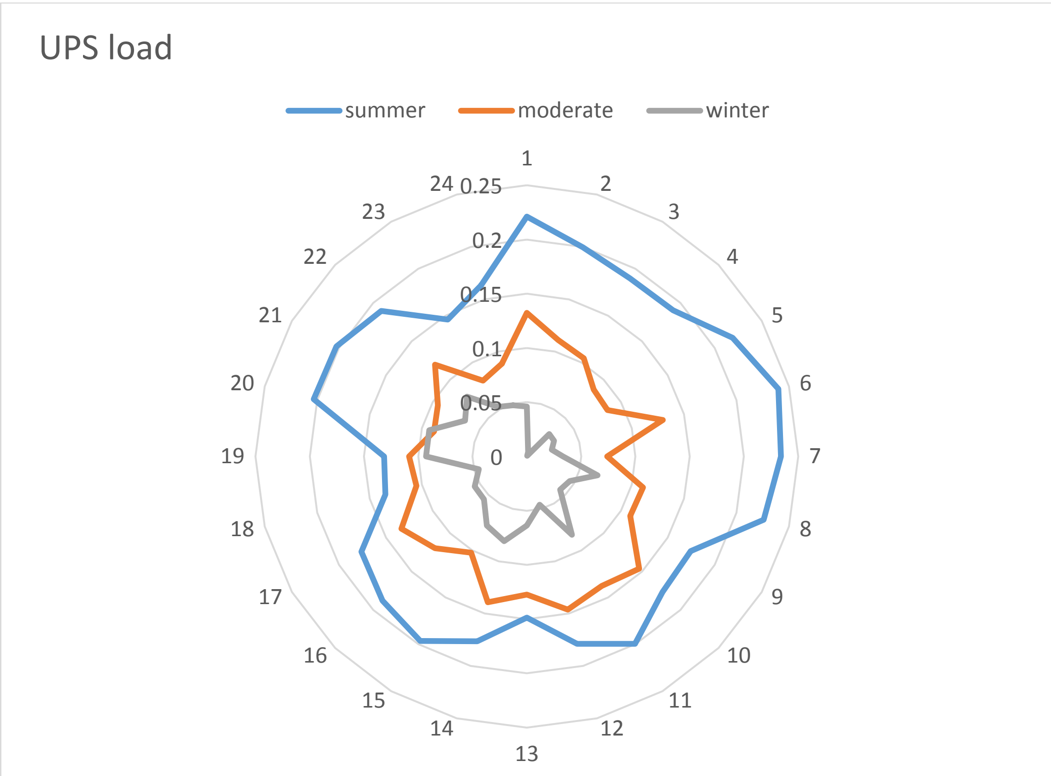


Figure 3-6 :UPS load pattern

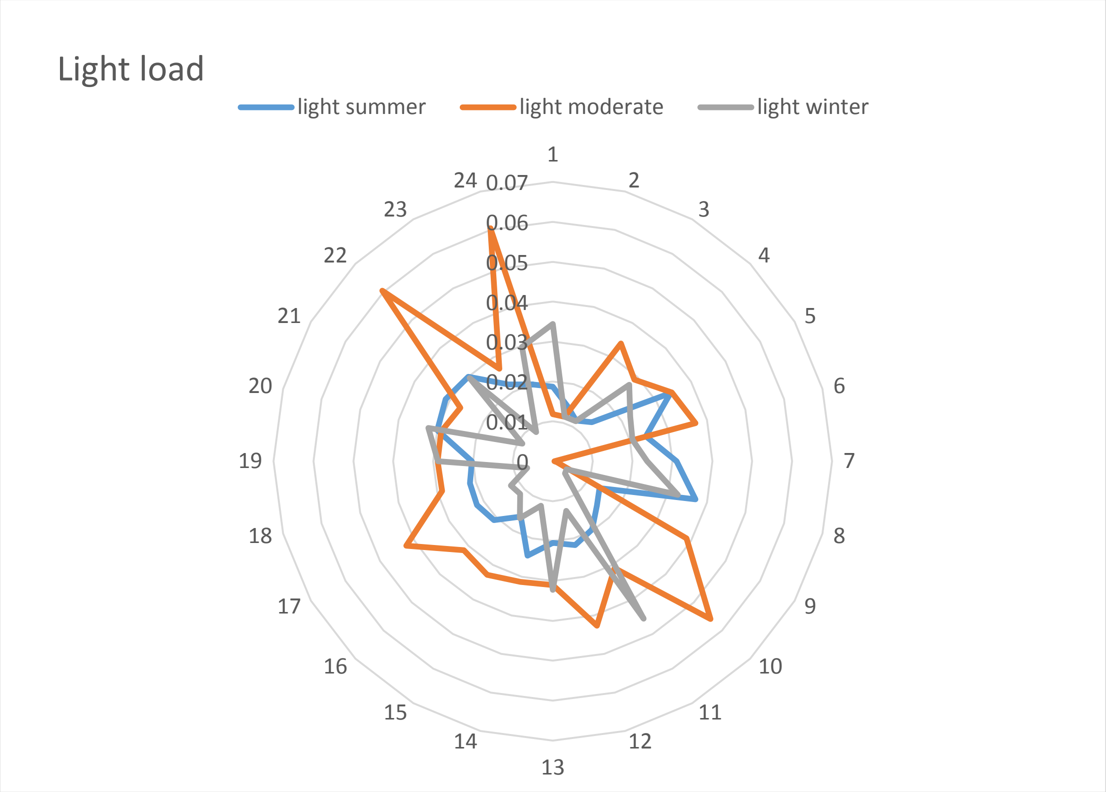


Figure 3-7: Light load curve

For the implementation and testing of the Nano grids, a complete scenario has been designed and verified with the average loads and requirements for the local area of the capital city where the major community of the city is middle class and elites are in minority. This makes the case favourable for the implementation of such a system as a pilot project[35]. Load curves have been artificially generated by the help of data acquired from survey of an average home in the city having two people in a single house hold where there is no electric cooling and heating system and then a detailed data has been synthesized by making it follow the trends of a detailed home data provided by URECk and Elexion ltd to validate the work in Europe and correlation to my own work which was nearest to our local profiles to incorporate authenticity of the human and social behaviour. The synthesized data follows the trends of the city perfectly and has been verified through reviews of public as well as experts. The average load curves throughout a day during different seasons is presented

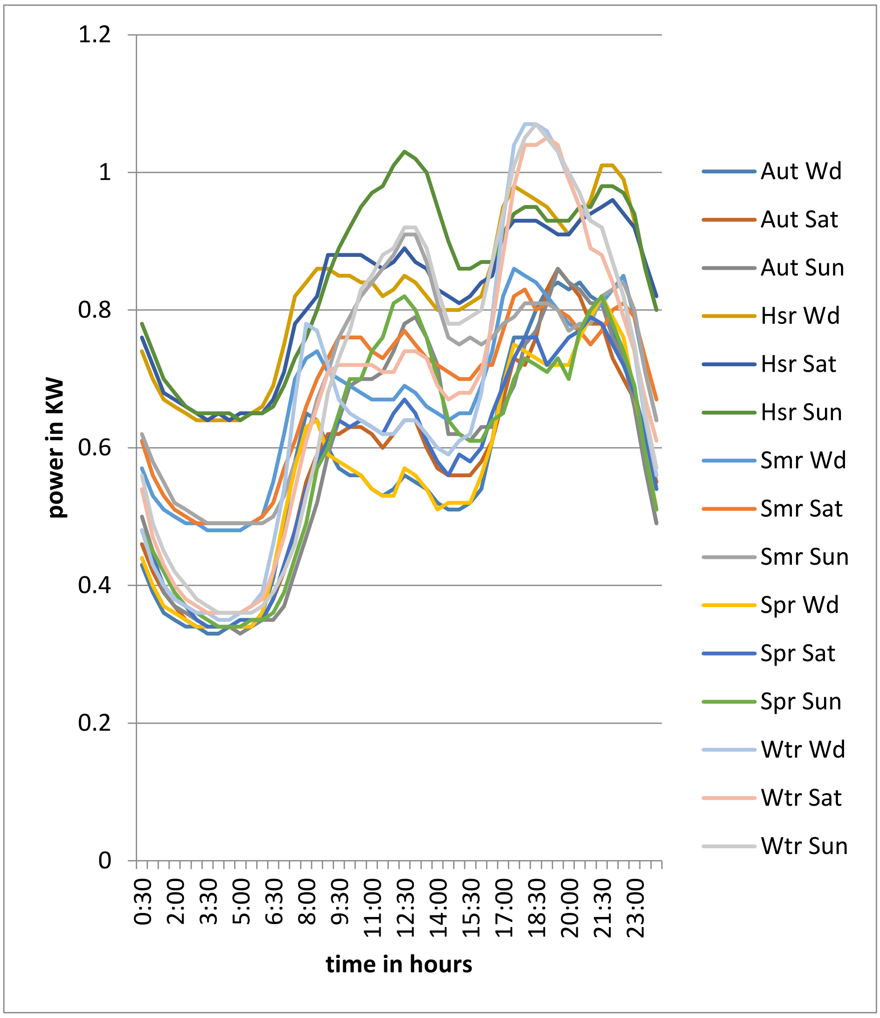


Figure 3-9: load curves in various weathers and days

The above load curve is optimally designed for 5 seasons which are autumn, winter, spring, summer and high summer. An average of week days, Saturdays and Sundays has been provided as evident from the above curve. It follows the climatic changes in the region perfectly. The entries of load shedding schedules in the area were obtained manually from the IESCO (Islamabad Electric Supply Company) for various seasons. These data sets were also used in the mathematical modelling for the testing purpose of various cases. Cars availability was obtained by observing and surveying the load pattern of various people of the same house hold which were taken as samples in the first place. The data was then linearized by using curve fitting tools as the values of cars being in home can either be one or zero in the model Therefore availability of car was taken as a binary variable in the system.

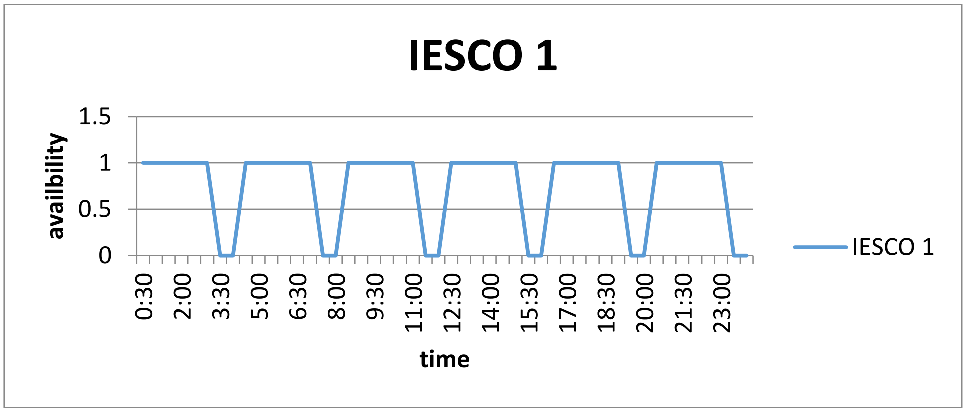
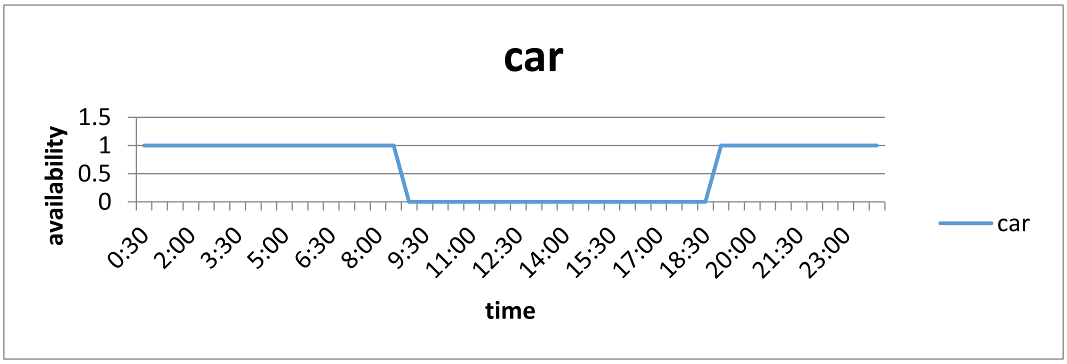


Figure 3-8: IESCO shedding pattern



load

Figure 3-9 cars average availability

Summary : The aforementioned data is then fed to the mathematical model of the Nano grid for all the above stated scenarios to test the penetration and effects of the vehicular batteries inside the grid and economically dispatch power to the load

Chapter # 4 :Optimization

A multi variable multi objective multi layered Genetic algorithm was used for the solution of the problem the cost function was as follows

Layer 1 was the time invariant optimization performed with genetic algorithm

$$\sum_{i=1}^{n} C_i b_i P_i = F \qquad (4)$$

b is the availability of a source required at the time, Pi represents the power at current time of a certain source ,n is the number of sources, F is the total cost at some power mix at an instant of time and C_i is the cost of individual power source

Layer 2 was implemented with the following cost [functions

$$\sum_{i=1}^{n} \sum_{t=1}^{N} C_{ti} b_{ti} P_{ti} = F(t) \qquad (5)$$

S.T

$$P_i^{\min} \le P_i \le O_i P_i^{\max} \qquad P_{s\max} = P_{is} + P_{i\_battery} \qquad \sum_i^n P_i \le P_t$$

(6,7,8)

S.t means with subject to while b is the availability of a source required at the time ,P represents the power at current time of a certain source is the number of sources, F is the total cost at some power mix at integral of time ,C is the cost of individual power source is the load at that time,F1 is the total power reduction, and Y is the type of load O is the wight assigned by the algorithm P_{is} is the solar power provided in the system $P_{i\_battery}$ is the power being sent to the battery by the solar system.

Here Y basically represents a 2 bit binary variable which is used to select the level of convenience as described earlier in the survey that the load has been divided into various levels of convenience according to the wishes of the people.

Following algorithm of multi layered GA was developed using multi objective GA tool of MATLAB.

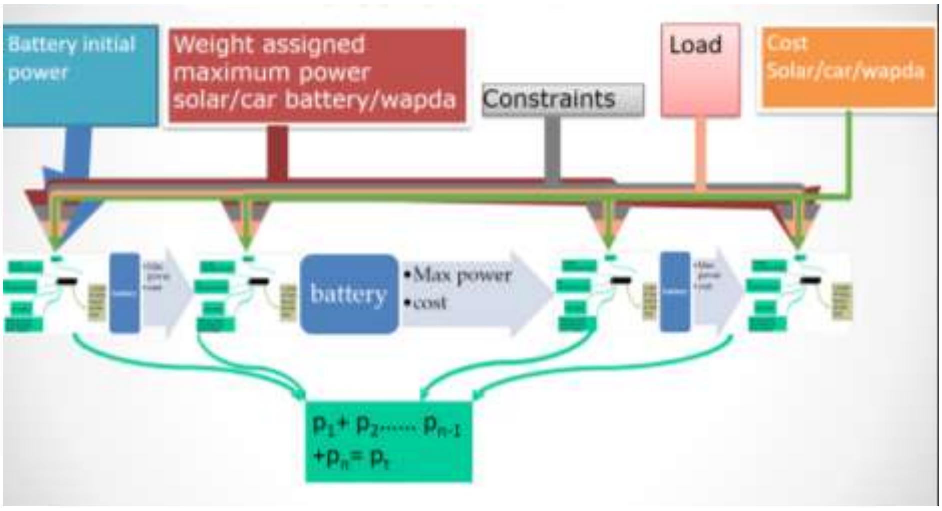


Figure 4-1:algorithm for economic dispatch time variant system

The algorithm here uses weighted maximum powers in the mathematical model explained above and thus the weights are controlled by the external layer of the genetic algorithm the final version of the system which performed hybrid demand side management as well as the economic dispatch simultaneously is as follows

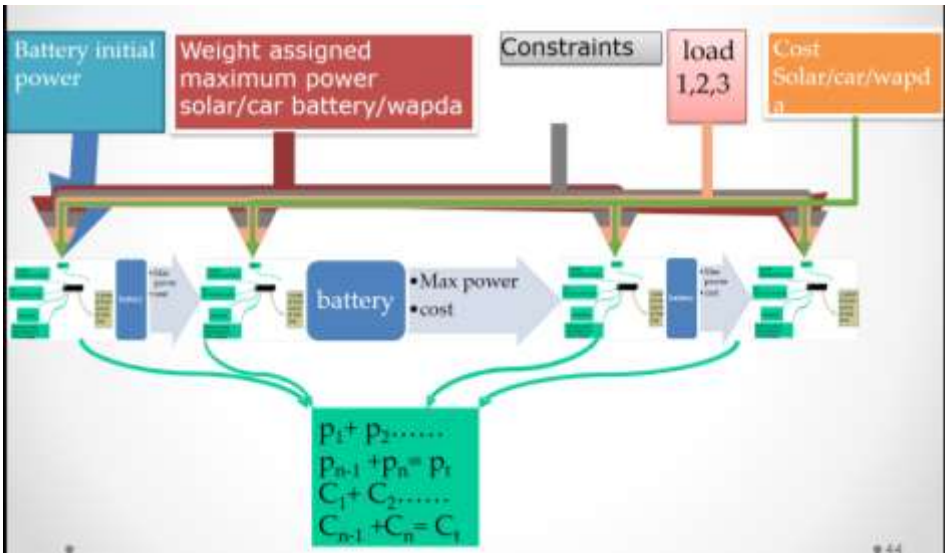


Figure 4-2 Algorithm for economic dispatch and demand side management combined

This algorithm is a multi-objective algorithm which minimizes the cost as well as the power being reduced or shortfall of the power in other words it minimizes the cost and maximizes the power output in a hybrid fashion. At a high abstraction level following diagram depicts all that is being done

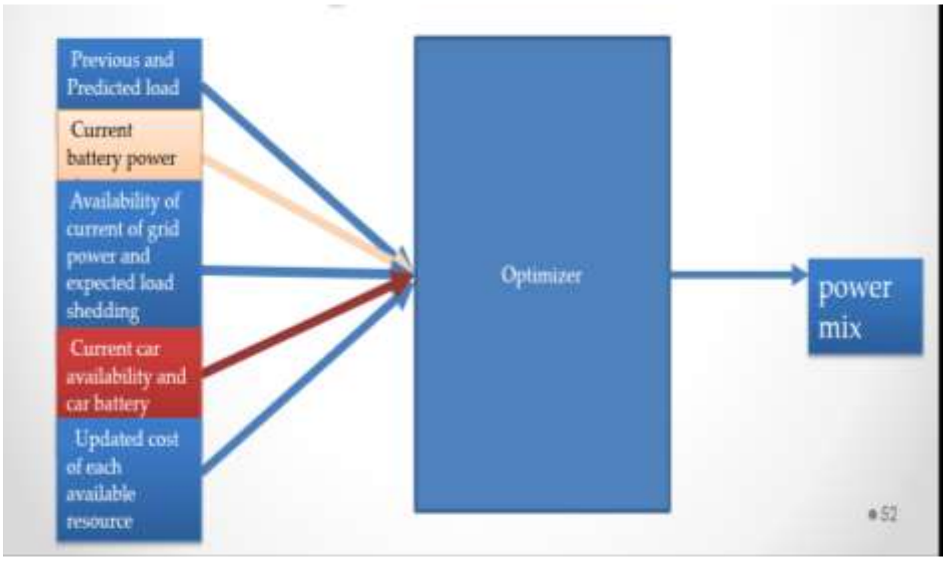


Figure 4-3 :Optimizer an outlook

Summary: Over all the optimizer was developed which has inputs for current battery power availability of max power via energy storage systems and un updated cost for all available resources.

Chapter # 5 :Results and Discussion

The mathematical model was implemented in Matlab with the data discussed in previous section. The results obtained showed a promising future for implementation of small scale Nano grids with V2G technology in Pakistan. For most of the months in the year, the power transferred to the loads was not only resultantly cheap but also an increase in power reliability was observed. Following are the power curves with the load shedding base case observed the power curves in various months show the power production and share of the source in meeting the demand

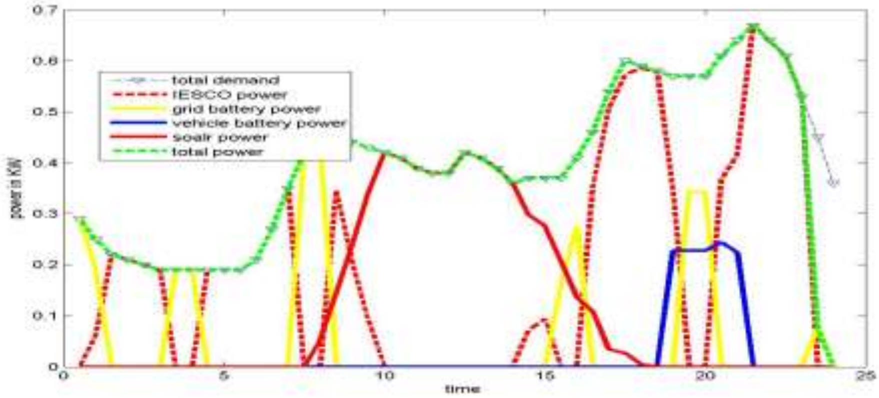


Figure 5-1: power transfer in the spring season

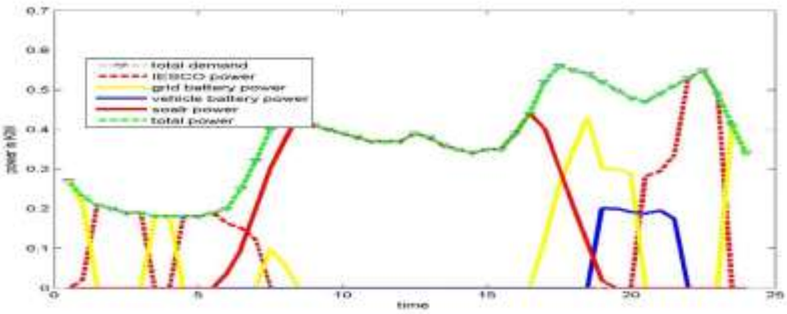


Figure 5-2 :power transfer in summer

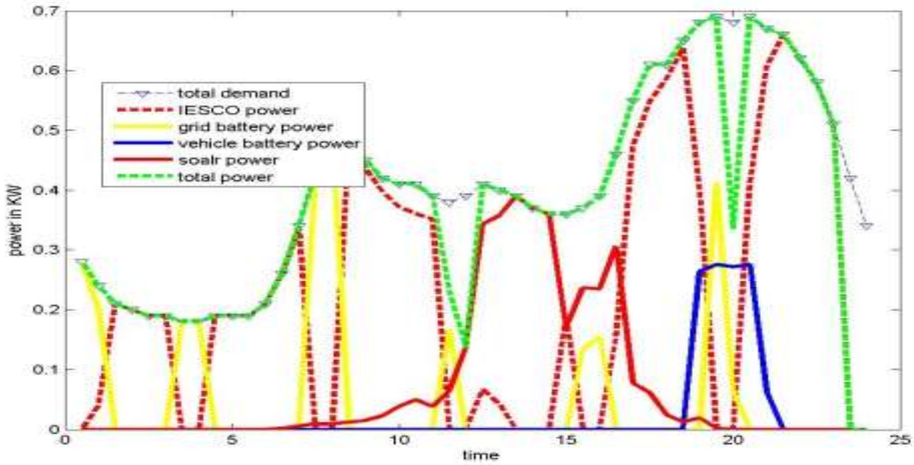


Figure 5-3 :power transfer in high summer

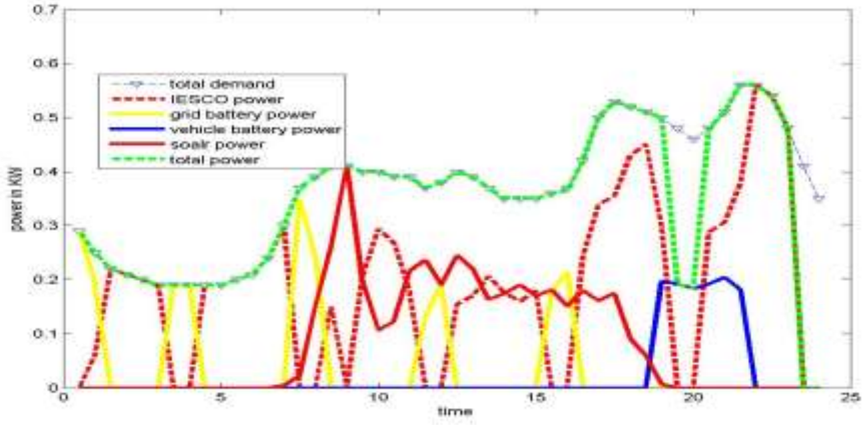


Figure 5-4 :Power transfer in autumn

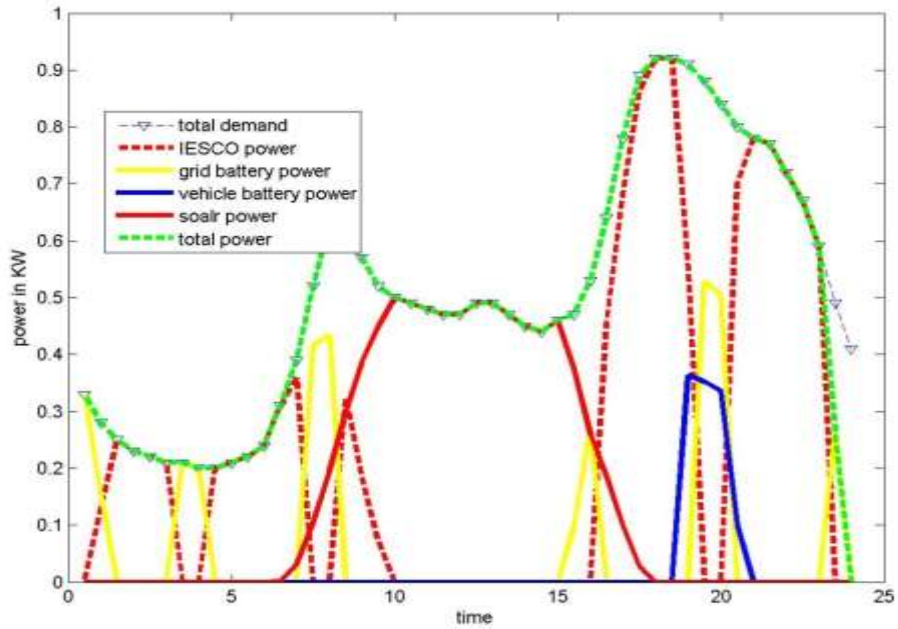


Figure 5-5 :Power transfer in winters

The overall power being transferred in the hours after midnight is being delivered through the grid battery banks and the IESCO power. After the sunrise, the power transferred takes a shift towards the renewable source namely solar PV while after the arrival of the car the power is taken from the car in the peak hours in which the electricity is costly This minimizes the cost of the overall power delivered to the loads. Specifically, partial power disruption in the peak hours can be seen in the 7th and 8th month which attributes to the loss of power in the IESCO and both the energy storages being unable to provide the power in this case the problem can be solved with demand side management in the local grid which is not at the moment within the scope of the research being conducted for this work.

Meanwhile the costs of the earlier shown power transferred are presented in the following graphs

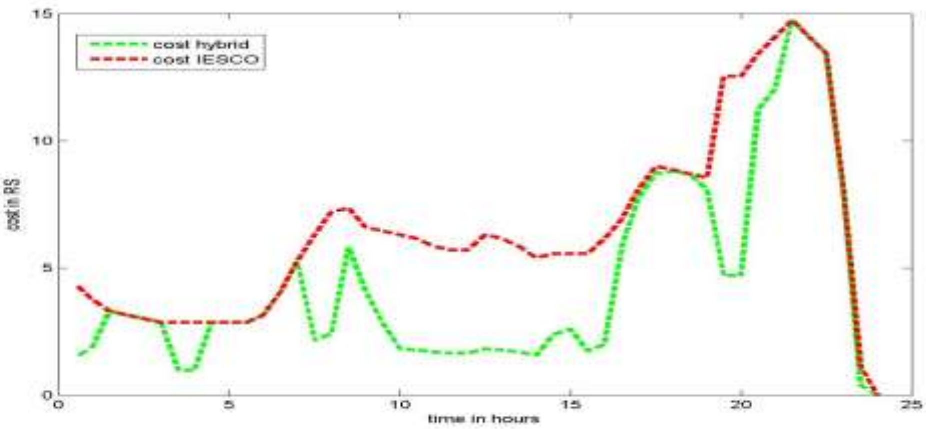


Figure 5-6: Cost incurred in the spring

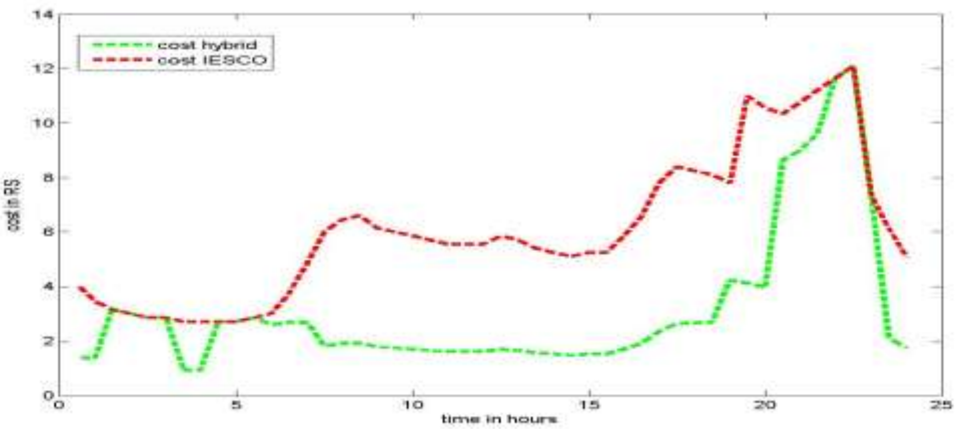


Figure 5-7: cost incurred in the summer

.

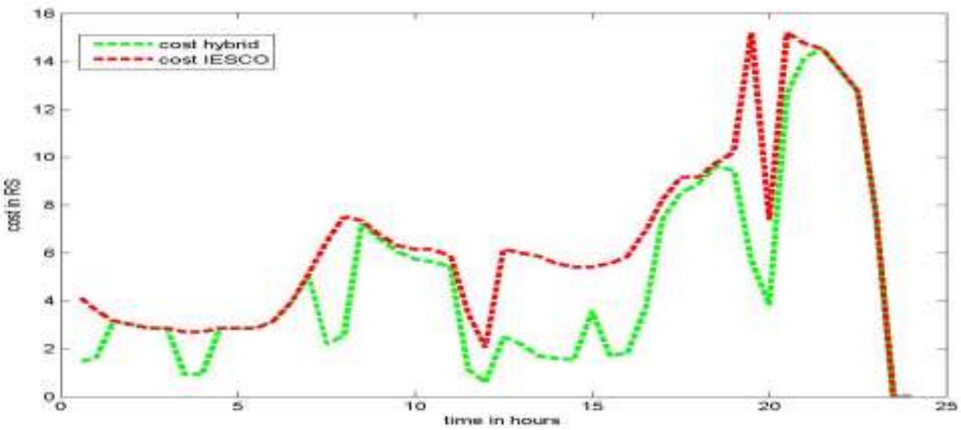


Figure 5-8 :cost incurred in the high summer

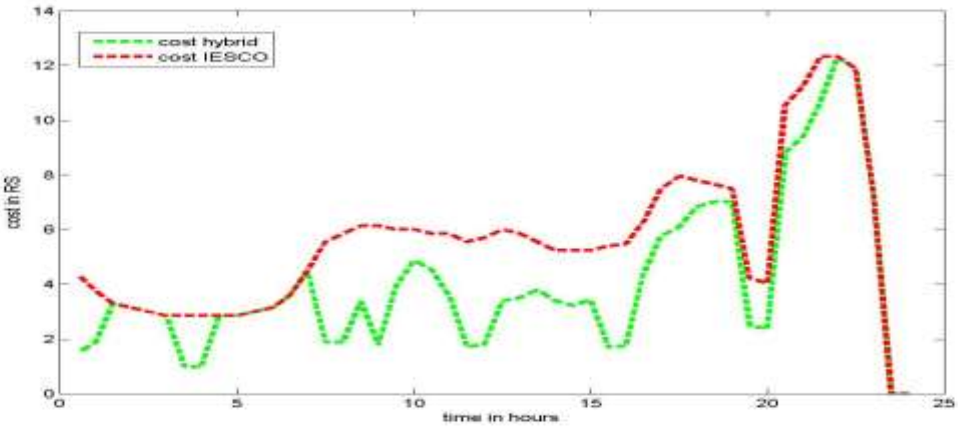


Figure 5-9 :cost incurred in the autumn

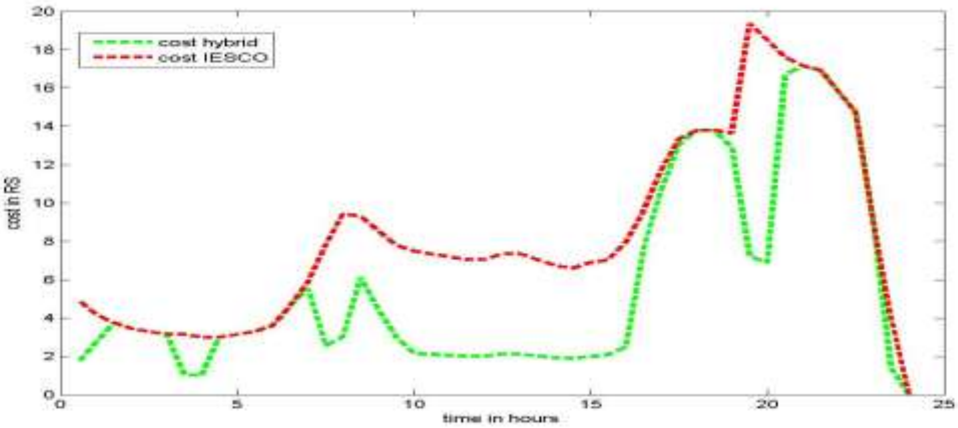
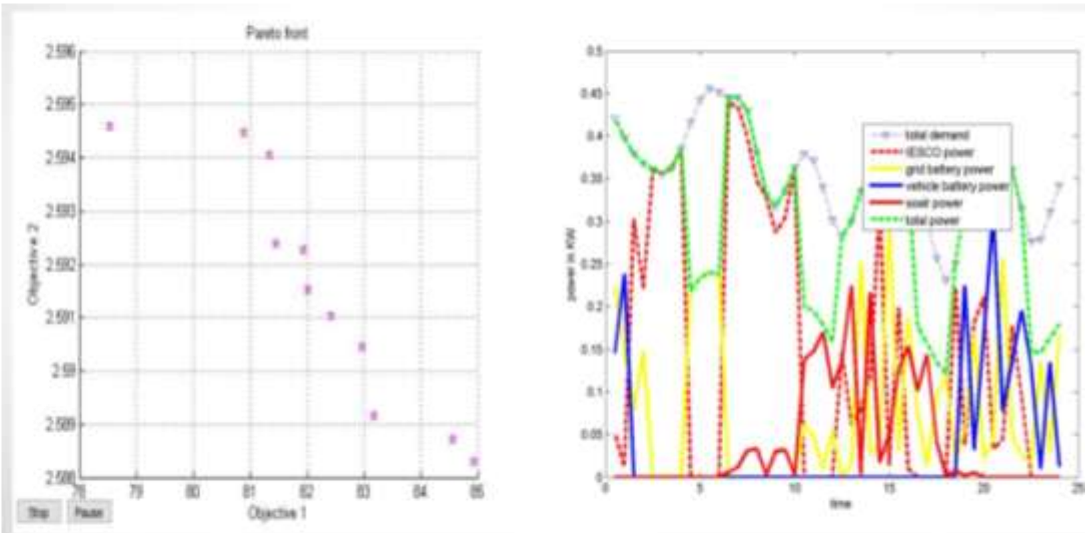


Figure 5-10 :cost incurred in the winter

The cost analysis shows the variation of the cost in the whole day. Again the graphs are consistent with the power transfer curves The most important thing to be observed here is the low cost of hybrid power supply in comparison with the IESCO power supply specifically in the time when electricity cost is high from the IESCO and the electricity being delivered to the load is very cheap. This effect is observed to be more prominent in the 3rd and 10^{th} month. The variations reduce when the battery banks and the solar are empty and the cost of hybrid and cost of IESCO reach the same point. A further point to be mentioned is that when the normal electricity supply from the grid is suffering from load shedding thus the power cost at that time comes out to be minimum in the whole system. This difference is only due to the power deficit which was observed in the previous power variation curves. This variation also indicates that with correct optimization the costs may be minimized over the specific time period.

The above work was done on the data set of URECk and Elexion ltd. Which correlates with the datasets of Pakistan and the results validating the work done on the dataset of ours own. A similar analysis was fully performed on the data collected by hands in our case from the survey and following results were found out from the optimization of the system which were being validated by the results of the previous attained data these were performed with the multi objective system and petro fronts are being shown for the cost and the power reduced as shown in the previous objective function the work has been done on 3 data sets under variable conditions of solar radiation patterns mainly three



radiation patterns have been used the data was obtained from NUST MHP station.

Figure 5-11: Pareto front and power transfer curve for load 1

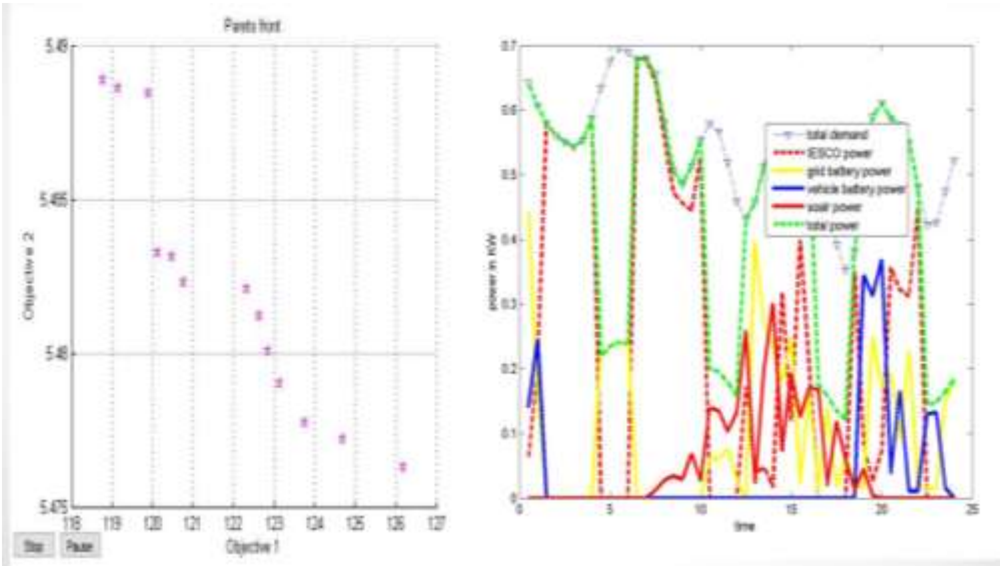


Figure 5-12: Pareto front and power transfer curve for load 2

Here the most optimized results of the generations are being shown in the pareto fronts which is basically showing the individually optimized output of various points the graph on the left is showing a successful implementation of the above explained algorithm at times 5 o clock in the morning 4 o clock and 11 o clock in the evening are the times which show the reduced loads in the first graphs similar is the case with the 2nd one but on a different convince level. The relevance with the results the similar kind of algorithm could not be applied to the previous data set of UK because I did not have the data sets of devices or various convince levels that is why cost graphs have been added to prove a subsequent decrease in cost while the above graphs prove that the algorithm can decrease the prices here the pareto plots show that multiple fitness points can be used here users preference can be taken into account that what he wants to go for if he was more weight to the power supply or the cost as all the point being shown here are the optimal points been calculated by the 2nd layer of GA applied as shown above. Similar graphs have been sow n for different load patterns as described earlier in the data collection work being shown for the other cases. The algorithms both layers being applied are being performed by a validated GA tool of MATLAB so the optimization points being shown in the graphs are the ones that have converged on cost and power loss both are only being shown in the pareto graphs.

Still the developed system is an optimizer's algorithm not a power production system the system will for sure fail so a result for higher demand was generated to show the limits of the system which are as follows

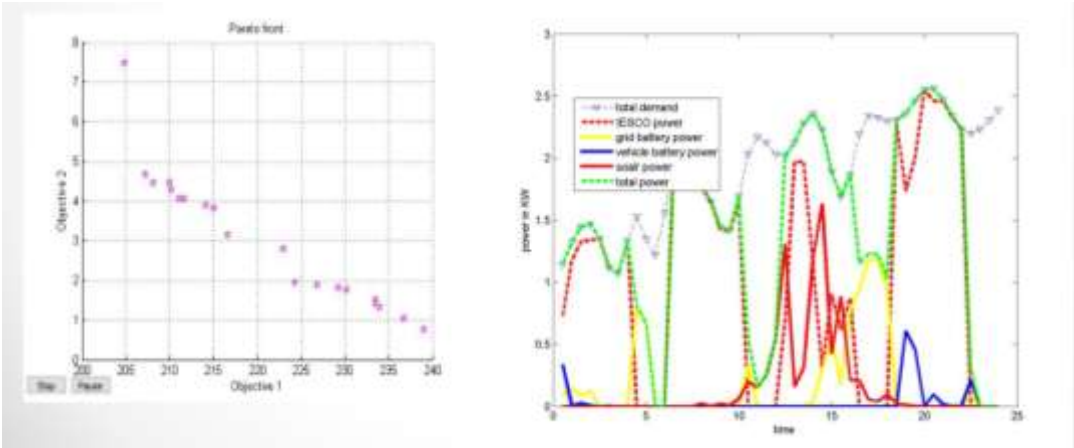


Figure 5-13: Pareto front and power transfer curve for worst

Here the demand grows to such a high level that the over all power constants are not met and the system fails at the times at which it should have had provided with the lower convince levels such a case can for sure occur in the case of badly sizes power system or when extra loads are being attached to the system.

As it has been discussed in the previous sections that the market capture of the cars in Pakistan is increasing thus the share of hybrid cars would also increase due to the new government policy of reduced duty on hybrid cars introduced in year 2015 and resultantly the aforementioned solution in the thesis becomes more efficient if all the cars are connected to the system but with the hybrid vehicles battery the major disadvantage of the work comes out to be the cost of the batteries, as the model explained earlier shows that the cost of battery has been included as a per unit price. The further studies show that this cost rises up to 60 Rs thus creating a problem for this connection. Prius was used for the calculations which uses NiMH batteries. These batteries are expensive while the latest work is being done on lead acid batteries in electric vehicles but at this moment no such hybrid vehicles are available in the country.

The effect of the vehicle integration with the grid can be clearly seen on the curves as the vehicle batteries are supporting the power management and power pricings moreover it is also observed that the system is running at an overall lower cost on the contrary the solar systems is unable to provide the sufficient charging to the batteries and thus the main stream power from the IESCO is hindered.

Summary : The system discussed in the thesis can be made as the base for work required on the smart Nano grid policies which if made can be extremely beneficial. The technologies discussed in the section have very nominal operation costs making it easy to be maintained after the installation. But arranging such capital intensive investments at a community level without the patronage of government appears to be the greatest hurdle.

Conclusion

The work presented in this work critically analyses the scenario of Pakistan's current energy state and tries to find a possible solution for the country in form of the vehicle integration into the Nano grids moreover the Nano grid concept surely shall improve the energy crisis for the country as it is evident from the results. But with better policies more improvement can be made if the explained model is implemented. The work shall not only reduce the power shortage but also have a major effect on the economy of the power production as the people themselves shall be harnessing the fruits of their own investments. Although its implementation is capital intensive but the payback time period is low resulting in an extremely low cost power production facility after a payback time period.

References

[1] E. Engineering, "Effects of Electricity Tariffs on Optimal Battery Energy Storage Sizing in Residential PV /Storage Systems," pp. 1072–1077, 2013.

[2] M. R. Aghamohammadi and H. Abdolahinia, "A new approach for optimal sizing of battery energy storage system for primary frequency control of islanded Microgrid," *Int. J. Electr. Power Energy Syst.*, vol. 54, pp. 325–333, 2014.

[3] S. M. H. Ali, M. J. S. Zuberi, M. A. Tariq, D. Baker, and A. Mohiuddin, "A study to incorporate renewable energy technologies into the power portfolio of Karachi , Pakistan," *Renew. Sustain. Energy Rev.*, vol. 47, pp. 14–22, 2015.

[4] I. N. Kessides, "Chaos in power : Pakistan ' s electricity crisis $," vol. 55, pp. 271–285, 2013.

[5] M. Tahir and M. Corresponding, "Dilemma of Third World Countries - Problems Facing Pakistan Energy Crisis a Case-in-Point," vol. 7, no. 5, p. 5539, 2012.

[6] M. a. Sheikh, "Energy and renewable energy scenario of Pakistan," *Renew. Sustain. Energy Rev.*, vol. 14, no. 1, pp. 354–363, 2010.

[7] M. Shahbaz, N. Loganathan, M. Zeshan, and K. Zaman, "Does renewable energy consumption add in economic growth? An application of auto-regressive distributed lag model in Pakistan," *Renew. Sustain. Energy Rev.*, vol. 44, pp. 576–585, 2015.

[8] A. B. Awan and Z. A. Khan, "Recent progress in renewable energy – Remedy of energy crisis in Pakistan," *Renew. Sustain. Energy Rev.*, vol. 33, pp. 236–253, 2014.

[9] "N ational P ower P olicy," 2013.

[10] N. Transmission, "COMPANY," 2014.

[11] Z. Wang, S. Member, B. Chen, J. Wang, S. Member, J. Kim, and M. M. Begovic, "Robust Optimization Based Optimal DG Placement in Microgrids," vol. 5, no. 5, pp. 2173–2182, 2014.

[12] A. B. Awan and Z. Ali, "Recent progress in renewable energy – Remedy of energy crisis in Pakistan," vol. 33, pp. 236–253, 2014.

[13] W. Uddin, B. Khan, N. Shaukat, M. Majid, G. Mujtaba, A. Mehmood, S. M. Ali, U. Younas, M. Anwar, and A. M. Almeshal, "Biogas potential for electric

power generation in Pakistan : A survey," *Renew. Sustain. Energy Rev.*, vol. 54, pp. 25–33, 2016.

[14] A. Raja and R. S. Abro, "Solar and wind energy potential and utilization in pakistan," vol. 5, pp. 583–586, 1994.

[15] S. H. Latha and S. Chandra Mohan, "Centralized power control strategy for 25 kw nano grid for rustic electrification," *2012 Int. Conf. Emerg. Trends Sci. Eng. Technol.*, pp. 456–461, 2012.

[16] M. R. Khan and E. D. Brown, "DC nanogrids: A low cost PV based solution for livelihood enhancement for rural Bangladesh," *2014 3rd Int. Conf. Dev. Renew. Energy Technol.*, pp. 1–5, 2014.

[17] S. Z. Farooqui, "Prospects of renewables penetration in the energy mix of Pakistan," *Renew. Sustain. Energy Rev.*, vol. 29, pp. 693–700, 2014.

[18] T. O. Be, P. In, T. H. E. Gazette, and E. Ordinary, "National Electric Power Regulatory Authority (NEPRA)," pp. 1–22, 2015.

[19] M. Asif, "Sustainable energy options for Pakistan," vol. 13, pp. 903–909, 2009.

[20] A. W. Bhutto, A. A. Bazmi, and G. Zahedi, "Greener energy: Issues and challenges for Pakistan-hydel power prospective," *Renew. Sustain. Energy Rev.*, vol. 16, no. 5, pp. 2732–2746, 2012.

[21] E. Reihani, S. Sepasi, L. R. Roose, and M. Matsuura, "Electrical Power and Energy Systems Energy management at the distribution grid using a Battery Energy Storage System (BESS)," vol. 77, pp. 337–344, 2016.

[22] J. Y. Ye, T. Reindl, A. G. Aberle, and T. M. Walsh, "Performance Degradation of Various PV Module Technologies in Tropical Singapore," *IEEE J. Photovoltaics*, vol. 4, no. 5, pp. 1268–1274, 2014.

[23] D. A. R. Barkhouse, O. Gunawan, T. Gokmen, T. K. Todorov, and D. B. Mitzi, "Device characteristics of a 10.1% hydrazine-processed Cu2ZnSn(Se,S)4 solar cell," *Prog. Photovoltaics Res. Appl.*, vol. 20, no. 1, pp. 6–11, 2012.

[24] N. A. Amoli, "Operational Flexibility Enhancement in Power Systems with High Penetration of Wind Power Using Compressed Air Energy Storage," 2015.

[25] A. R. Bhatti, Z. Salam, M. J. B. A. Aziz, K. P. Yee, and R. H. Ashique, "Electric vehicles charging using photovoltaic: Status and technological review," *Renew. Sustain. Energy Rev.*, vol. 54, pp. 34–47, 2016.

[26] Department of Energy & Climate Change, "UK Renewable Energy Roadmap Update 2013," no. November, 2013.

[27] C. Flavin, G. Milena, M. A. Maria, O. Alexander, D. R. Maria, and P. Tagwerker, “Study on the Development of the Renewable Energy Market in Latin America and the Caribbean,” *Int. Dev. Bank*, no. November, 2014.

[28] M. Hannifan and N. W. Technologies, “to Improve the Electric System on the Duck Valley Reservation Technical Contact :,” vol. 3759, 2004.

[29] A. Alaidroos, L. He, and M. Krarti, “Feasibility of Renewable Energy Based Distributed Generations in Yanbu , Saudi Arabia,” *World Renew. Energy Forum*, pp. 1–8, 2012.

[30] A. Rouhani, “Feasibility Study and Developing Appropriate Hybrid Energy Systems in Regional Level,” vol. 9, no. 3, pp. 270–277, 2015.

[31] R. V. O. Nederland, “Market Study : PV Energy in Brazil,” 2015.

[32] M. S. Purser, “A Technical and Economic Feasibility Study of Implementing a Microgrid at Georgia Southern,” 2014.

[33] J. Delamare, B. Bitachon, Z. Peng, Y. Wang, B. R. Haverkort, and M. R. Jongerden, “Development of a Smart Grid Simulation Environment 1,” pp. 1–10.

[34] A. Molderink, V. Bakker, M. G. C. Bosman, J. L. Hurink, and G. J. M. Smit, “Management and control of domestic smart grid technology,” *IEEE Trans. Smart Grid*, vol. 1, pp. 1–10, 2010.

[35] M. H. Shwehdi and S. R. Mohamed, “Proposed smart DC nano-grid for green buildings — A reflective view,” *2014 Int. Conf. Renew. Energy Res. Appl.*, pp. 765–769, 2014.

Acknowledgements

I am thankful to my Creator Allah Subhana-Watala to have guided me throughout this work at every step and for every new thought which setup in my mind to improve it. Indeed I could have done nothing without Your priceless help and guidance. Whosoever helped me throughout the course of my thesis, whether my parents or any other individual was Your will, so indeed none be worthy of praise but You.

I am profusely thankful to my beloved parents who raised me when I was not capable of walking and continued to support me throughout in every department of my life.

I would also like to pay special thanks to all of faculty members of my department for their tremendous support and cooperation. Each time I got stuck in something, some of the faculty came up with the solution. Without their help I wouldn't have been able to complete my thesis. I appreciate their patience and guidance throughout the whole thesis.

I would also like to thank all the friends of mine who were my moral support and got me out of many tight spots during the work on the problem. Specifically Syed Ali Kazmi, Muhammad Khawar Nadeem, Mashood Ahmed. Hamza Admed Raza, Sufyian Naeem , Haider Ejaz and Shomaz ul Haq.

I would also like to thank Dr. Majid Ali, Mr. Akif Zia Khan and Mr. Atiq ur Rehman of for being there on my thesis help guidance and evaluation committee and express my special Thanks to Dr. Shehzad younis for his help. I am also thankful to Dr. Anjum Naveed, for his support and cooperation.

Finally, I would like to express my gratitude to all the individuals who have rendered valuable assistance to my study.

Appendix

DISTRIBTED GENERATION OF ELECTRICITY IN CURRENT AND FUTURE ENERGY SCANARIO OF PAKISTAN

[1]ABDUL KASHIF JANJUA, [2]AKIF ZIA KHAN,[3]MUHAMMAD BILAL KHAN

[1,2,3] United states Pakistan Centre for advanced studies in energy NUST Islamabad

Email: [1]ajanjua@asu.edu, [2] akif@casen@nust.edu.pk,[3] bilal@casen@nust.edu.pk

---

Abstract: Distributed generation is a very unique technology which is the holy grain of solution to Pakistan's energy crisis. The paper presents the application of distributed generation and its advantages for the current energy scenario in the country moreover it also discusses the future energy scenario in the country while it concludes with the implementation of various policies regarding the energy sector of the country.

Keywords :Distributed generation, smart grids, energy policies .

---

1. INTRODUCTION

Compressive consumption of energy is the most important factor to measure the economy and industrial prosperity of the country as well as the living standards of the country are known to be formed the precipitation energy consumption of the country. further more the increase in the energy consumption of the world is not distributed over the population uniformly the effect of this non uniform distribution is the disturbance of social system in all the underdeveloped countries. and more frequent thermal shock than their aircraft . In addition, many of these TBCs must cope with the increasing electric demand is causing major problems in policy and development of future energy resources in underdeveloped countries like Nigeria, Egypt, Bangladesh and Pakistan. This also has an impact on the eco system of areas. Pakistan is facing a very high deficiency of power which is causing the afore mentioned problems as the demand supply gap is increasing with time. Pakistan's prime location where most of the renewable resources are present in abundant potential. If such a integrated system is developed to tap all the resources collectively. National energy scenario of Pakistan is divided among various institutions such as power distribution transmission and generation companies while the renewable sector is being handled by the system PCRET, AEDB,NIST PCAT, SERC,NCAE and SEC. steps are being taken to improve the power sector as many new power plants using the indigenous resources have been developed

2. CURRENT SCANRIO OF PAKISTAN

2.1. Short falls in past decade

Pakistan despite having huge potential of various renewables mainly depends on the imported oil for the energy sector. Despite the import of this oil the electricity has a short fall of approximately five to eight thousand MW which is a huge difference which can be up to 22% of the maximum demand. This demand is around 25000 MW per year[4]. The demand of 22% is for 2014 which is less than the percentage shortfall in year 2008 which was 37%. The shortfall in the peak hours even go up to 50% in summer season plunging the country in long hours of darkness and causing a gigantic loss to the national exchequer. This demand is projected to increase in the future as the numbers of users are continuously increasing with the growing population of the country[5]. As the users have increased form 7.9 million to 19.9 million from year 1990 to year 2010[6], the demand in energy is predicted to increase to 163000MW by 2030 which has be to planned and long term energy generation goals have to be made According to Robert Hathways and Michell Kugelmn of Pakistan oxford university press, the energy short fall shall be around 32000 MW in 2030 if the development in energy generation systems is on the same pace as it was in the last decade[7]

2.2. Potential of renewable energy resources

Aforementioned stats stand valid only if the electricity generation is expanded at the same pace as it was done during previous two decades but the recent policies and priorities of government have changed and now energy production has gained extreme importance in the country. Water and energy are the most invested upon areas in the country with international aid from multiple donors also being poured in the same domains. Now new policies for the renewable resources are being made and implemented in the country which the country holds tremendous potential [5].

The potential of major renewable resources available in Pakistan is mentioned in table 1

Source	Energy available (GW)
Solar PV	1000
Hydro power	51700
Wind	3000
Biogas	5700

Table.1 Power potential of various renewables in Pakistan[8].

Where the present power generation from the thermal and hydel projects has been summarized in the following tables

Kot Addu Power Company Limited	Kot Addu,Muzaffar Garh, Punjab	1,600
Hubco Narowal Power Plant (HNPP)	Narowal ,Punjab	225
Bin Qasim Power Plant I	Karachi, Sindh	1,260
Bin Qasim Power Plant II	Karachi, Sindh	560
Jamshoro Power Station	Jamshoro District, Sindh	850
Lalpir Power Limited	Mehmood	362

	Kot,Muzaffargarh ,Punjab	
Altern Energy Limited	Fateh Jang,Punjab	29
Atlas Power Limited	Sheikhu pura,Punjab	225
Attock Gen Limited	Rawalpi ndi,Punjab	165
Fauji Kabirwala Power Company	Kabirwa la,Punjab	157
Gul Ahmad Energy Limited	Karachi, Sindh	136
Nishat Power Limited	Lahore, Punjab	200
Nishat Chunian Limited	Lahore, Punjab	200
Sapphire Electric Company Limited	Muridke ,Sheikhupura District,Punjab	234
Saba Power Company Limited	Farooqa bad,Sheikhupura, Punjab	125
Southern Electric Power Company Limited	Raiwind ,Lahore	136
Tapal Energy Limited	Karachi, Sindh	126
Japan Power Generation (Pvt) Limited	Raiwind ,Punjab	135
Kohinoor Energy Limited	Lahore, Punjab	131
Sitara Energy Limited	Jaranwa la,Faisalabad,Punj	85

	ab	
Saif Power Limited	Sahiwal ,Punjab	225

Table.2 Power production by private sector in Pakistan[9]

The hydel and nuclear power plants are as follows

Dam	Power
Duber Khwar Dam	130MW
Jabban	22MW
Gomal zam dam	17MW
Khankhwar	72MW
Jagran	30MW
Chitral	1MW
Renala	1Mw
Kurram Garhi	4MW
Nandi pur	14Mw
Tarbela	3578MW
Mangla	1000MW
Ghazi-Barotha	1450MW
Warsak	243MW
Nuclear power	Plants
Chashma	184MW
Dargai	20MW
Rasul	22MW
Shadi-waal	13.5MW

Table 3: hydal and nuclear power plants

2.2. Future scenario

Due to the aforementioned problems the planning commission and government jointly proposed many power plants at various locations in the country and following are the ones which are being made currently

Plant	Capacity MW	type	place
Thar power plant	100	thermal	Tharparkar,islamkot,sindh
Grange holding power plant	163	thermal	Arifwala punjab
Jhang RLNG power project	1230	LNG	Haveli bahadur shahmjahang
Balloki kasur RLNG based power project	1000-1200	LNG	Kasur
Jamshoro coal power project	600	coal	Jamshoro sindh
k-electric coal power plant	660	coal	Karachi sindh
Thar power plant	660	Thermal	Tharparkar,Sindh
Thar coal power plant	1320	Coal	Tharparkar
Muzaffargarh sugarcane husk power project	120	husk	Muzaffargarh, Sindh
Maple leaf	40	coal	Mianwali

power			
Neelum-jhelum power plant	969	Hydal	Azad jamu kashimir
Golen gol hydro power	106	Hydal	Chitral
Patrind hydro	147	Hydal	Abbottabad,muzafarabad
Bhasha dam	4500	Hydal	Chilas gilgit
Keyal hydro power	128	Hydal	Kohistan KPK
Dasu dam	4320	Hydal	Dassu KPK
Karot hydro power	720	Hydal	Rawalpindi district
SK hydro power	840	Hydal	Kaghan velly mansehra

Table 4: proposed power plants

The resultant energy mix of power by sectors is as follows

source	Percentage contribution
Thermal (GENCOs)	19.4
Hydel(WAPDA)	30.1
Nuclear(PAEC)	3.1
IPPs(thermal)	36.8
K-electric(thermal)	8.6
Rental(thermal)	2

Table.5 Power mix of various sectors in Pakistan[10]

The thermal fatigue test was done in a thermal cyclic furnace. The specimens were tested at 600^0C highest temperature. Heating and cooling time were kept as 10 minutes. When the samples were cooled to the ambient temperature, they were taken out, dried and put into the high temperature furnace again, repeating the same process. More than 90% of the cracked regions of the surface of TBC systems were adapted as the criterion for the failure of the coating. The weight changes of the samples were measured to a precision of 0.5 mg by an analytical balance. Three number of specimens were tested and average was considered for analysis.

3. DG SOURCES FOR PAKISTAN

3.1. Scope of DG sources in Pakistan

Distributed generation sources are the most diversified combination of electricity generation for any area[11].Mostly the term distributed generation (DG) is defined in different perspectives and in various ways as in literature various authorities have defined it according to their own assessment and focus of research. Distributed generation sources are used to provide active power for the distributive network directly. This ensures many advantages such as the reduction in power losses, better economic dispatch operation, area specific network generation, reduction in transmission losses, high reliability, improved power quality, dispersed energy production, less carbon foot prints and improved power capacity. Despite of some of the demerits of deploying DG sources such as the bidirectional power flow causes reduction in voltage regulation and causes voltage unbalance in the system, sufficient headway has been made in this technology and such systems can be easily implemented in the developing countries like Pakistan.

With the advent of distributed generation sources, more penetration of renewable energy sources at distribution network level has become possible making it easy for the network operator to perform monitoring, regulation and corrective actions. Power produced by renewables is intermittent and dependent upon meteorological conditions. Since these conditions vary along the geographic terrain of a country therefore geographic dispersion of renewables is preferred for maximum utilization of different diversified renewable sources This deployment scheme of renewables allow near uniform energy to be fed to the power grid. Therefore, energy production from renewables and geographically distributing them across the grid can help to increase the reliability of the renewables and overcome their intermittency issue. In such a configuration, there will be no need to raise the bar of system spinning reserves requirement

Pakistan has been bestowed by Mother Nature with a prodigious weather and a rich geography. From sky touching and the world’s tallest mountain ranges of Himalaya, Karakoram and Hindu Kush in north to the 1046 km coastline in the south and widespread stretches of scorching desert along eastern border with India and Western border with Iran, Pakistan experiences an extremely diverse weather simultaneously throughout the country posing an ideal condition for the installation of different diversified distributed renewable source. Some of such DG sources and there potential location in Pakistan are

Source	Location
Micro Hydro	Gilgit Baltistan, KPK, Azad Jammu And Kashmir
Wind Turbines	Gharo, Jamphir, Ketty Bandar, Karachi Up To Hyderabad, Islamabad And Some Areas Of KPK
PV	Bahawalpur, Thar And Cholliston Deserts In Punjab And Sindh While Quetta And Peshawar In KPK And Baluchistan
Solar Thermal	Bahawalpur Thar And Cholistan Deserts In Punjab And Sindh
Biomass Based Generation	Central Punjab And Upper Sindh
Fuel Cell Based Generation	Areas With High Hydrogen Production Potential Like Through Thar Coal
Ocean Energy	Coastal Area Of Karachi And Makran

Table.6. area dependent renewable energy potential of various places [6]

3.2. current developments

The current scenario of energy harnessing from diversified DG sources in Pakistan is getting better with each passing day. Micro hydro plants have been installed in KPK and Gilgit Baltistan, producing total of more than 8 Mw[12]. Similarly, bio gas installations are producing 1800m^3/day. Incumbent government has set the ambitious targets of increasing the production of these sources by approximately 100 % till 2020[13]. Similarly, substantial investment is being done in the solar PV sector such as Quaid e Azam solar power park with a cost of 131 million dollars and a capacity of 100 MW[14].

Energy harnessing from these diversified distributed renewable sources is beneficial if these sources are integrated with the national grid tackling their intermittency issue. However, in the event of islanding operation such as in Nano grids, relying on a single source of renewable energy poses a serious threat to system security and integrity as simultaneous existence of various resources in a small community is only coincidental. [15].As clear from the above table that every source has great potential in the country but the problems of energy reliability are being introduced in the case of small targeted area[16].

Introduction of energy storage systems can help to increase the reliability of the system at a certain cost making system more robust to contingencies. If such infrastructure is implemented at various locations on small scale community level, the power sector of the country can get a great lift to fight the energy crisis. Such small setups of community scale come in the category of Nano or micro grids. This paper gives a brief overview about the introduction and architecture of a Nano grid using DG sources in Pakistan.

CONCLUSIONS

The escalating energy demand of the country is forcing the government to make the policies more flexible, attractive and favorable for the foreign investors and for the local bodies to invest in this lucrative area as the same is reflected by the efforts of incumbent government. During the previous decade there was no focus on renewable resources Feed in tariff was very time consuming and long licensing procedures made it difficult for the renewables to be incorporated into the government systems[17].

Pakistan's energy sector has always faced issues regarding to policy. No initiative have been taken on formulation of a detailed and a combined energy policy, normally ad-hoc based policies and bills have been passed in parliament and no concrete single policy has been formed .It is clear from the discussion done in this paper that policy has a very close relationship with technology implementation and cost effectiveness of new technologies[18][19]. Some extremely suffering technologies are shale gas and coal mining technologies. Pakistan's energy policy over the span of some decades is as follows.

In 1994 the first framework for the private power generation was produced and implemented to meet with the increasing energy deficient. An improvement was made after approximately one decade in 2002 which encouraged the IPPS to be made and produced giving the major boost to power production. Rental power plants and thermal power plants were deployed as a result of this policy change in next five years .First proper framework for the new IPPs was provided by PEPCO in 2006 which covered the renewable energy production to a small extent. This was the first policy which paved the way for the renewable energy investment. This was elaborated in year 2009 giving more detail to the renewables.

The recent power policy of 2013 has a vision of affordable and efficient energy production and utilization making it very clear that the government is encouraging people and making such policies to ensure the energy conservation and affordability of energy as well as trying to cope up with the energy deficit in the country. On the other hand the scope of production, taken into account from 2008 onwards is more flexible than only targeting the IPPs (independent power plants) but now it is coming to captive cum grid spill power projects on small scale and captive power projects for self-use and dedicated use. Recently in 2014 net metering policy was introduced in the country[13].

Despite the efforts being put into the policy making and giving fringe benefits to the people a certain lag is being observed in the politics where the policy makers have failed to do successful lobbying in the parliament and which results into countless discussions over various bills tabled in the parliament resulting in negative impact upon the energy sector of the country. No policies for implementation of Micro/Smart Grids have been introduced in Pakistan although huge quantum of work was done during the USAID funded Power Distribution Project (PDP) started in 2010 to implement some aspects of the smart grids at distribution company (DISCO) levels by installing smart energy meters, implementing substation automation and retrofitting of different thermal energy units. PDP project was more focused on the capacity building of human resource and increasing the utilization of existing infrastructure. Load management has been highly improved from power distribution project (PDP). Major work has been done with all nine distribution companies; 119MW of power has been secured by capacitive bank installation in grids for power factor improvement which has saved approximately 133 million us dollar to the government. More than 50,000 smart meters have been installed in the target locations at substation level. However, fully functional pilot project of implementing Smart Grid architecture in its true letter and spirit for a specific region as of Islamabad is still seen as a distant dream[20].

REFERENCES

[1] E. Engineering, “Effects of Electricity Tariffs on Optimal Battery Energy Storage Sizing in Residential PV /Storage Systems,” pp. 1072–1077, 2013.

[2] M. R. Aghamohammadi and H. Abdolahinia, “A new approach for optimal sizing of battery energy storage system for primary frequency control of islanded Microgrid,” *Int. J. Electr. Power Energy Syst.*, vol. 54, pp. 325–333, 2014.

[3] S. M. H. Ali, M. J. S. Zuberi, M. A. Tariq, D. Baker, and A. Mohiuddin, “A study to incorporate renewable energy technologies into the power portfolio of Karachi , Pakistan,” *Renew. Sustain. Energy Rev.*, vol. 47, pp. 14–22, 2015.

[4] I. N. Kessides, “Chaos in power : Pakistan ’ s electricity crisis $,” vol. 55, pp. 271–285, 2013.

[5] M. Tahir and M. Corresponding, “Dilemma of Third World Countries - Problems Facing Pakistan Energy Crisis a Case-in-Point,” vol. 7, no. 5, p. 5539, 2012.

[6] M. a. Sheikh, “Energy and renewable energy scenario of Pakistan,” *Renew. Sustain. Energy Rev.*, vol. 14, no. 1, pp. 354–363, 2010.

[7] M. Shahbaz, N. Loganathan, M. Zeshan, and K. Zaman, “Does renewable energy consumption add in economic growth? An application of auto-

regressive distributed lag model in Pakistan," *Renew. Sustain. Energy Rev.*, vol. 44, pp. 576–585, 2015.

[8] A. B. Awan and Z. A. Khan, "Recent progress in renewable energy – Remedy of energy crisis in Pakistan," *Renew. Sustain. Energy Rev.*, vol. 33, pp. 236–253, 2014.

[9] "N ational P ower P olicy," 2013.

[10] N. Transmission, "COMPANY," 2014.

[11] Z. Wang, S. Member, B. Chen, J. Wang, S. Member, J. Kim, and M. M. Begovic, "Robust Optimization Based Optimal DG Placement in Microgrids," vol. 5, no. 5, pp. 2173–2182, 2014.

[12] A. B. Awan and Z. Ali, "Recent progress in renewable energy – Remedy of energy crisis in Pakistan," vol. 33, pp. 236–253, 2014.

[13] W. Uddin, B. Khan, N. Shaukat, M. Majid, G. Mujtaba, A. Mehmood, S. M. Ali, U. Younas, M. Anwar, and A. M. Almeshal, "Biogas potential for electric power generation in Pakistan : A survey," *Renew. Sustain. Energy Rev.*, vol. 54, pp. 25–33, 2016.

[14] A. Raja and R. S. Abro, "Solar and wind energy potential and utilization in pakistan," vol. 5, pp. 583–586, 1994.

[15] S. H. Latha and S. Chandra Mohan, "Centralized power control strategy for 25 kw nano grid for rustic electrification," *2012 Int. Conf. Emerg. Trends Sci. Eng. Technol.*, pp. 456–461, 2012.

[16] M. R. Khan and E. D. Brown, "DC nanogrids: A low cost PV based solution for livelihood enhancement for rural Bangladesh," *2014 3rd Int. Conf. Dev. Renew. Energy Technol.*, pp. 1–5, 2014.

[17] S. Z. Farooqui, "Prospects of renewables penetration in the energy mix of Pakistan," *Renew. Sustain. Energy Rev.*, vol. 29, pp. 693–700, 2014.

[18] T. O. Be, P. In, T. H. E. Gazette, and E. Ordinary, "National Electric Power Regulatory Authority (NEPRA)," pp. 1–22, 2015.

[19] M. Asif, "Sustainable energy options for Pakistan," vol. 13, pp. 903–909, 2009.

[20] A. W. Bhutto, A. A. Bazmi, and G. Zahedi, "Greener energy: Issues and challenges for Pakistan-hydel power prospective," *Renew. Sustain. Energy Rev.*, vol. 16, no. 5, pp. 2732–2746, 2012.

SMART NANO GRID A SOLOUTION TO PAKISTAN ENERGY CRISIS

[1]ABDUL KASHIF JANJUA, [2]AKIF ZIA KHAN,[3]MUHAMMAD BILAL KHAN

[1,23,]United states Pakistan Centre for advanced studies in energy NUST Islamabad

Email: [1]ajanjua@asu.edu, [2] akif@casen@nust.edu.pk,[3]bilal@casen.nust.edu.pk

Abstract: This paper presents an overview of the architecture for smart Nano grids, Integration of various diversified distributed generation technologies in Nano grids at small community level and different policies governing its implementation. The paper also reviews the current energy scenario of Pakistan with emphasis on the need of setting up small scale Nano grids with integration of V2G technology for decentralization and deregulation of the currently wrecked power sector of Pakistan. Various load profiles along with load shedding schedules have been tested under the simulation of the presented Nano grid architecture. The promising results obtained after running the simulation testify the fact that integration of vehicles at small community level can provide a viable solution to eradicate the menace of energy crisis by offering peak shaving and demand side management benefits.

Keywords :Distributed generation, smart grids, Nano grids

1. Smart Nano grids

A small scale grid which has been implemented at community level to cater the local needs of energy production, distribution and consumption is called the Nano grid. A very recent definition to it is that Nano grid provides an infrastructure for power and information communication technologies where at least one power sink and one power source should exist with availability of power gateway to the outside electric companies while storage can or cannot exist in the grid. Some researchers also define the Nano grids as aggregation and interconnection of various generators having total production around 20kW to provide power in area spread of 5 km radius of a central point.[1]

2. Grid architecture

A smart grid has a conventional grid architecture with some advancements like balancing of demand and supply on various time scales, forecasting of power production and loads in various time scales. This is only possible by augmenting some extra functionality present in the existing system which mainly base upon monitoring data management and analysis of power flow of the grid at various predetermined point . It involves multiple layer of abstraction from the physical to communication to data mining and data analysis layer and ultimately to control layer

Similar grid architecture is implemented on a Nano grid scale. The difference is only in the size of the system which puts a constraint on funds and hardware usage on the system so more sophisticated system is required for Nano grids which are equally or nominally less efficient than that of the national grids but extremely responsive to various parameters and resultantly produce same results as in the micro or national grids in terms of power and cost efficiency.

` The scale of the Nano grids restricts the costs and it also gives us various advantages as the area to which the grid is to be implemented is extremely small and can be easily monitored controlled and protected through various networking protocols. It reduces the usage of extremely fast communication devices which add up a huge amount to the grids system.

1.3 VEHICLE TO GRID POWER

The installation of DG sources in Nano grids is dependent on the geography and meteorological conditions moreover it also depends upon the vehicle to grid and vehicle to house (V2G and V2H) technologies. There are various energy storage systems that are already present around us but are not being used efficiently. Some of these are the overhead water storage systems available in every community and the hybrid electric vehicles (HEV) battery banks. Such energy storage devices have recently been pondered upon and people are now exploiting these resources.

Resultantly new energy storage systems are connected to the grid. These particular energy storage systems are very small but now available in form of hybrid and electric vehicles When power from Electric Vehicles (EV) or Hybrid Electric Vehicles (HEV) is fed to the home energy management system or to the grid they are formally known as vehicle to grid (V2G) and (V2H) vehicle to house technologies[2]

V2G and V2H technologies are an efficient use of available redundant energy storages. On the other hand, the use of these energy storages also requires extreme care in handling and coordination with other available vehicles in the community. The prediction of future energy productions, available power and loads all must be available and optimally coordinated with the grid controller else transport from the vehicle will be compromised.

Algorithms are being made for the efficient extraction and insertion of energy in electric banks of the vehicles when plugged into the grid outlet. Both technologies require basic electric devices for the electricity conversion .Inverters, converters, DC regulators and frequency regulators are necessary aforementioned technology[3].

The quality of the technology is that it can behave as electric load when surplus power is available and a generator when the power is limited due to unavailability of any DG source in the grid system.

DG sources have been recommended by various studies for different countries having high DG source potential. Some major reports were made are as follows

Country	Sources
UK	Onshore wind, offshore, hydro, solar PV, wave and tidal, bioenergy
USA (Caribbean and Latin America)	Hydropower, wind power, solar PV, biomass, Geothermal, CSP
USA rural utility service at duck valley	Wind power, solar power(PV,CSP),
Saudi Arabia	Solar PV
Iran	Geo thermal, wind power, solar PV coal oil and gas
brazil	Solar PV
USA Georgia southern	Solar PV, wind, bio power, fuel cell,

university	hydroelectric.

Table1 : renewable usage in countries

This paper presents a perspective of implementation of Nano grids in Pakistan. The previous discussion has strongly proved that the energy sector is lagging and extreme short fall of electricity has to be seen in the country which forces the government and the local population to take preventive measures and build the energy production facilities. Large power production facilities being out of the scope of local community and social circles of the country make the small scale Nano grids and micro grids implementation for the local community very attractive. Here there are various driving factors for the people and small investors to focus upon the Nano grids as they provide a very bright future for the energy conservation of the country. The next sections of the paper present the impact of such system involving the V2G technology and solar technology at Nano Scale level to offer ancillary services to relieve the burden from overstressed national grid

The immature technology and non-availability of electric vehicles forces the users to be unable to experience the fruits of V2G technology fully but sale of cars in Pakistan is on upward trend due to the introduction of the leasing by banks on nominal interest thus increases the possibility of hybrid cars quick introduction in the country. According to the PAMA (Pakistan automotive association), the sales of cars above 1300cc was 121816 in year 2014 Most of the cars in the country are not even hybrid but the prospect still remains. Toyota Prius is the car which is normally seen on the roads. The total annual car sale is given in the following diagram

The above graph indicates that the number of new cars being sold in the country has an increasing trend and the gradient is increasing with the time. This paper gives a brief analysis on the prospects of the implementation of V2G technology in the country and how it can help in the energy scenario explained above for the economic development of the country.

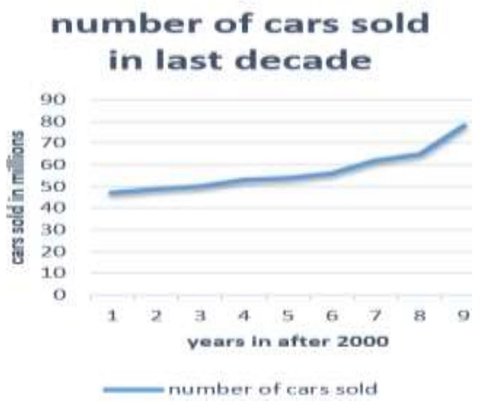


Fig 1: number of cars sold in last decade

3 MODELING AND SIMULATION

3.1. Grid model

A mathematical model of the grid has been implanted in the paper for the sake of testing V2G technologies to help in the economic dispatch through various sources inside the Nano grid namely solar grid battery and vehicular battery. The model restricts its self to the power and costs of electricity and does not deal with the fault analysis and power quality in the grid. Despite these power sources it can be used to increase the power reliability and power quality in the system.

The model uses the commercially available converters and inverters in itself, moreover it only uses the power and cost efficiencies of the electronics modeled. Thus a very reliable data in terms of power and cost can be found in the results.

The architecture of the grid has been laid as illustrated in the figure

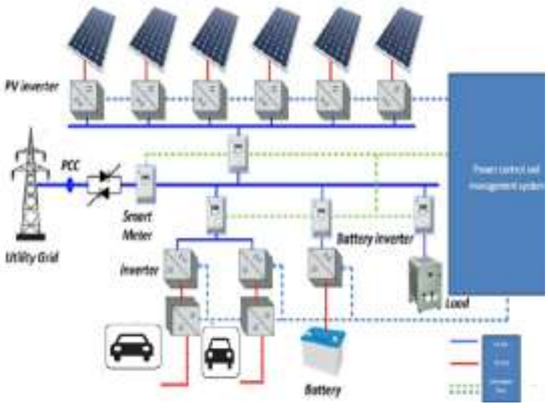


Fig2 : smart grid architecture

The above diagrams shows the structure of the Nano grid[4]. where the load may or may not be depending on the characteristics of the Nano grid. As clear from the basic diagram, the grids major users may be of any type but the total power cap should be small. The working models of such grids are being developed in Bangladesh, India and various other countries. Model implemented for the testing purpose of this paper is presented in above figure .

Specification	Value
Annual sun shine hours of Islamabad	3090 Hrs.
Total solar capacity	1KW
Initial cost of solar system (panels plus wiring)	200000RS
Solar payback time period	7 years
Annual Operation and maintenance cost	10000Rs
Life of inverter used	4 years
Efficiency of solar panel	17.4%
Cost of IESCO unit	14.5 Rest , 18Rs(7pm to 11 pm)
Voltage of grid battery	12v
Voltage of vehicle battery	12v
Cost of grid battery	10000 Rest
Cost of vehicle battery	3000RS
Number of cycle grid	400 cycles

battery	
Number of cycles vehicle battery	300 cycles
Ampere hours of grid battery	200amph
Ampere hours of vehicle battery	80amph
Depth of discharge of grid battery	0.4
Depth of discharge of vehicle battery	0.6

Table 2: specifications of the system

The annual sunshine hours of Islamabad were calculated from the tables provided by met department of Pakistan The data for solar power has been taken from the solar intensity falling in Islamabad from metronome. The cost of the solar panels, inverter battery including specifications, have been taken from local venders 'Nizam solar systems' offering Rs. 110 per watt cost of Yingli solar panels. IESCO unit was taken from the bills of IESCO. The model has been made to be a run time problem solver using the current values on load vector and the solar intensity vector to produce the power output vector for the grid thus giving the economic dispatch results over horizon of 24 hours. The model works on a priority based power transfer to the load in the grid The conditions are predetermined

The cost calculation of the IESCO power is taken from the power sources but the cost per unit being provided through the other sources is calculated through following mathematical equations

$$cost\ per\ unit_{solar} = \frac{\left(cost_{solar_{initial}} + (oem_{solar}.*\ lifetimesolar)\right)}{365 * lifetimesolar * capcity_{total}}$$

$$cost\ per\ unit_{battery} = \left(\frac{cost_{bat_{grid}}}{\left(number_{of\,cycle_{grid}}\right) * amph_{grid} * voltage_{batt_g}} \right. * 1000 + (cost\ per\ unit_{solar} * 1.18)$$

Where 1.18 is the power loss factor in the charging and recharging in the battery Cost of vehicular battery is determined by the same formulae like the one used for grid battery storage For the implementation and testing of the Nano grids, a complete scenario has been designed and verified with the average loads and requirements for the local area of the capital city where the major community of the city is middle class and elites are in minority. This makes the case favorable for the implementation of such a system as a pilot project[5]. Load curves have been artificially generated by the help of data acquired from survey of an average home in the city having two people in a single house hold where there is no electric cooling and heating system and then a detailed data has been synthesized by making it follow the trends of a detailed home data provided by URECk and Elexion ltd working in Europe which was nearest to our local profiles to incorporate authenticity of the human and social behavior. The synthesized data follows the trends of the city perfectly and has been verified through reviews of public as well as experts. The average load curves throughout a day during different seasons is presented in fig

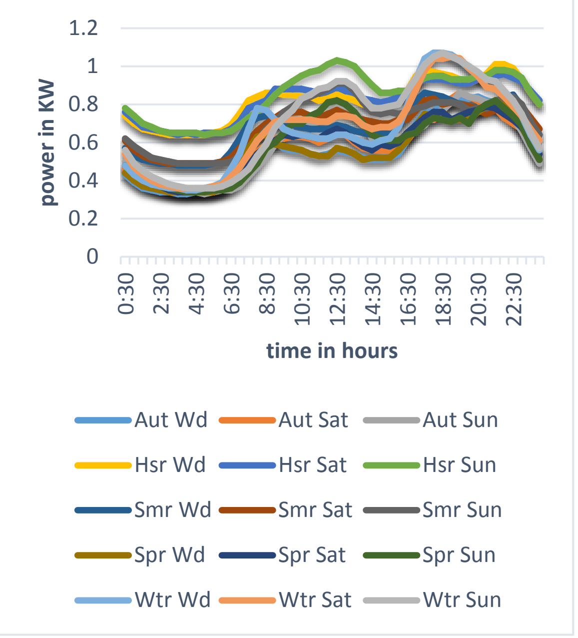


Fig 3: load curves

The above load curve is optimally designed for 5 seasons which are autumn, winter, spring, summer and high summer. An average of week days, Saturdays and Sundays has been provided as evident from the above curve. It follows the climatic changes in the region perfectly. The entries of load shedding schedules in the area were obtained manually from the IESCO (Islamabad Electric Supply Company) for various seasons. These data sets were also used in the mathematical modeling for the testing purpose of various cases. Cars availability was obtained by observing and surveying the load pattern of various people of the same house hold which were taken as samples in the first place. The data was then linearized by using curve fitting tools as the values of cars being in home can either be one or zero in the model Therefore availability of car was taken as a binary variable in the system.

Genetic algorithm was applied to optimize the cost unction and the optimization produced the following results for the costs incurred along a single day

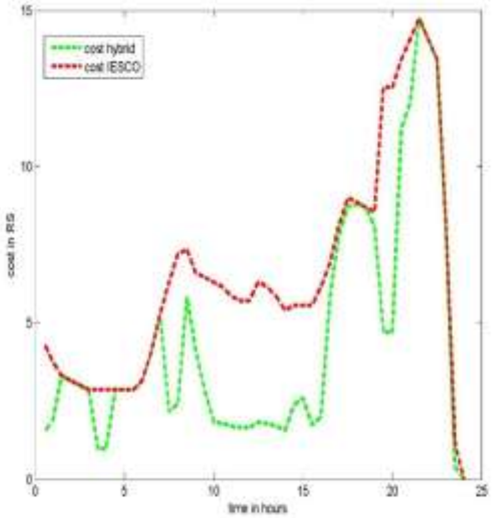


Fig 4: cost of electricity per hour

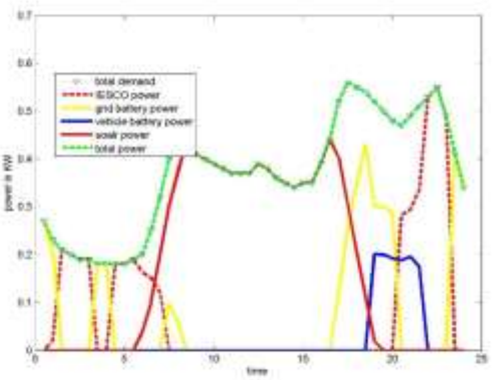


Fig5 : power usage by different sources

The technical details of such a grid and the commercial technology available in Pakistan enable us to use it for the implementation of the idea that is being presented in the paper.

CONCLUSIONS

The work presented in this paper critically analyses the scenario of Pakistan's current energy state and tries to find a possible solution for the country in form of the vehicle integration into the grid and the Nano grid concept surely shall improve the energy crisis for the country as it is evident from the results. But with better policies more improvement can be made if the explained model is implemented. The work shall not only reduce the power shortage but also have a major effect on the economy of the power production as the people themselves shall be harnessing the fruits of their own investments. Although its implementation is capital intensive but the payback time period is low resulting in an extremely low cost power production facility after a payback time period.

REFERENCES

[1] M. Ahmed, U. Amin, S. A. Qureshi, and Z. Ahmed, "Implementation of Nanogrids for Future Power System," vol. i, no. 1, pp. 133–139, 2014.

[2] W. Zhang, F. C. Lee, and P.-Y. Huang, "Energy management system control and experiment for future

home," *2014 IEEE Energy Convers. Congr. Expo.*, pp. 3317–3324, 2014.

[3] A. R. Bhatti, Z. Salam, M. J. B. A. Aziz, K. P. Yee, and R. H. Ashique, "Electric vehicles charging using photovoltaic: Status and technological review," *Renew. Sustain. Energy Rev.*, vol. 54, pp. 34–47, 2016.

[4] A. Molderink, V. Bakker, M. G. C. Bosman, J. L. Hurink, and G. J. M. Smit, "Management and control of domestic smart grid technology," *IEEE Trans. Smart Grid*, vol. 1, pp. 1–10, 2010.

[5] M. H. Shwehdi and S. R. Mohamed, "Proposed smart DC nano-grid for green buildings — A reflective view," *2014 Int. Conf. Renew. Energy Res. Appl.*, pp. 765–769, 2014.