# Comprehensive Analysis of Electric Power System: State, Vulnerabilities, Limitations, Consequences and Challenges

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***Abstract*** The existing electric power transmission and distribution system seems to be incapable to accommodate the irresistible energy crisis, the rising supply, demand gap, the consumers need and more importantly fail to resist supply theft in the country. The rising darkness in the country has become a challenge for everyone to facilitate customer and run business. Industries are closing and unemployment turns into crime. Considering present situation, the core objective of this paper is to identify flaws in the system and their impacts. In this regard, the comprehensive study of energy system performed along with its current structural distribution, flow and govern the body framework to discover the weakness, threats and challenges. Which will be valuable to identify root causes of exiting the situations and also helpful in future work or solutions that specifically targeting real problem and avoid recurrence. The results found ground-breaking facts that not only affecting the country status in global perspective, but also a barrier in the development, industrialization and urbanization. While, the govern authorities focus on adding more power to a system which is not an enduring solution to control the energy situation. On the contrary, the power energy companies suffering from unbearable huge circular debts which gradually increases and losing significant ratio of the GPD every year. The paper discusses all these areas in depth with statistics and findings, highlighting the underline problems and recommendation to overcome the current situation.

**Keywords** — Energy System, Electric Power System, Energy Crisis, T&D Loss, NTL Loss, Circular Debt.

## I. INTRODUCTION

Pakistan is suffering from brutal energy crisis since 2008s, which is rooted back in early 1990s[1]. This influence is seen in nearly all areas of national and personal life: agricultural, industrial, textile, business & development, social life (meeting, parties, communication, education, research, etc.), living standards, and the growth of the economy is directly affected[2]. The demand of energy is proportionally increased and coupled with the population growth rate, urbanization, and industrialization, agricultural growth, electrification of rural areas, rising per capita income rate, economical actives and other services[3]. Which means no one can impede developmental activities, nor want to prevent it.

The world is evolving and moving towards building more flourishing society and engaging in making the environment better. To make it promising, many industries' development around the globe require a significant amount of energy. Among all other energy resources, electricity is the only energy means which hold a unique status across the worthwhile by virtue of its fact. To control the energy demand and consumption, many developed and underdeveloped countries as well as international bodies express their irresistible attentiveness in getting rid of energy crisis. But, the inefficient use of energy and its wastages has caused the ever increasing demand-supply gap and exerts strong pressure on the existing energy resources which leads to an electricity crisis in the country. Collectively, it resulted in the worst load-shading in history, which is about 12 to 16 hours in various regions of country[4]. It is also recorded as 18 to 20[5] hours in some region(s) during last five years. Currently, the primary sources of energy of country are highly reliant on oil and gas[6]. Whereas the respective national companies predict that old reserve of nation will vanish by the year 2025. Overcoming these issues required a more thoughtful study, sincerity and political free decision making instead of focusing on power generation, neglected supply system[7].

In the past two centuries, energy turns into the most eminent resource of life as air. There is no doubt that energy is cautiously evolving and its utility encompasses a complete range of day to day activities of human life. This ranges from cooking, washing, dwelling, communication, transportation, business, trade, factories and other industrial works that are greatly dependent upon availability of energy resource[3][5]. Nowadays, energy becomes the hot and most discussed topic. Countries and people are more concerned about energy availability and its existence as all the natural resources will end soon in future. As well, it is taken as the lifeline or backbone of productivity and success of the revolution and rapid development of countries. It becomes a vital element in any sort of activity or service requires because of its capability to lighten

**TABLE I**
**ELECTRICITY CAPACITY, GENERATION, SUPPLY, DEMAND AND T&D LOSS SINCE 2008**

| Ref | Year | I.C (MW) | C.D (MW) | M.D (MW) | S.E (GWh) | T.S (GWh) | T&D Loss in % | Net Gen. Loss (GWh) |
|---|---|---|---|---|---|---|---|---|
| **[20]** | 2015 | 24,906 | -47 | 24,022 | 1,08,866 | 95,979 | 19.87 | 19,364 |
| **[21]** | 2014 | 24,953 | 1336 | 23,505 | 1,05,810 | 93,777 | 19.60 | 18,605 |
| **[22]** | 2013 | 23,617 | 371 | 17,534 | 98,630 | 87,080 | 20.12 | 17,762 |
| **[23]** | 2012 | 23,246 | -927 | 17,658 | 99,296 | 89,721 | 20.46 | 18,353 |
| **[24]** | 2011 | 24,173 | 1910 | 16,928 | 1,00,583 | 90,549 | 20.85 | 18,877 |
| **[25]** | 2010 | 22,263 | 1638 | 16,871 | 99,856 | 87,432 | 22.82 | 20,360 |
| **[26]** | 2009 | 20,625 | 487 | 16,771 | 94,664 | 82,702 | 22.63 | 19,091 |
| | 2008 | 20,165 | 484 | 16,498 | 97,451 | 84,584 | 22.87 | 19,729 |

up, run machineries, empower equipment and devices[8]. Consequently, it is holding a pivotal share and plays an imperative role in improving the living standards and industrialization of nations across the world. Its generation cannot be underestimated and is highly accountable for country prosperity and economic growth[6].

In the reformed world, the human civilization and urbanization demand for energy constantly rises. The growing requirement concern with the security of energy, availability of adequate, sufficient and affordability is prerequisite for economic growth and progressive. Globally, the extensive reliance on energy has become an imperative challenge for hospitalization, poverty, living standards and development of country[9]. In the present environment, electricity is providing basic facilities such as education, business, health, refrigeration, water purification and for appliances working. It is crystal clear that energy is a backbone of human activities and nation's development.

The paper is distributed over the following section. Wherein, Section 2 describes the existing structure of Pakistan power sector and electricity generation, transmission, and distribution to end users, supply, demand, recently developed and future power project of the country. Section 3 underlines some limitations of present transmission system. Section 4 highlights the vulnerabilities of the system; possible and in practice meter tempering and transmission hocking ways. Section 5 addresses the consequences of electricity theft. Section 6 is concerned with the challenges of providing load-shading free state, the availability of sufficient electricity supply. Section 7 summarizes the research facts and future work to overcome the electricity related problems.

## II. POWER SYSTEM

(The existing electricity system of Pakistan is ageing more than 80 years old. It was designed with the primary purpose to transmit the electric supply to the end point and keep the light on, which was design based on the need and requirements identified at that time. The essential elements of power system are Generation, Transmission and Distribution. These are also known as sub-systems of a power system. These sub-units or systems are connected by the Grid stations or also called the sub-stations[10][11]. Figure 1 illustrates the traditional power system process from generation to end-user supply.

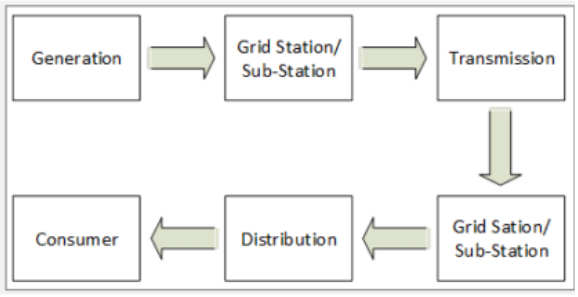


**Fig. 1: Power System Process Diagram**

Generating plant is built with three phase generators, a source of energy, prime mover, substation and control room. Energy source can be any resource that can produce electricity. The existing system utilizes the Fossils Fuels such as coal, gas, oil, Nuclear, Geothermal, Hydro and Solar. In simple words, at generation point, the energy of one source is converted to the electrical energy. It generates the low Alternating Current (AC) voltage[12]. Because it is easier convert AC voltage than Direct Current (DC) voltage[13]. Normally, the ordinary power plant generation capacity is about 11 to 13KV, which is economically good and feasible to setup as required[14]. As electrical energy produces, it is then transferred to the transmission grid. The transmission grid comprises of High tower caring high voltage power lines and sub-stations at both end[15]. The substation is located near the generation point used to step-up supply to high voltage that feeds power over long distance supply transmission. Before delivering this supply to end user consumption and unitization, it passes through the sub-station where it is stepping down high voltage power to low voltage (120v/220v) or consumable supply at local grid stations[10].

The energy Transmission and Distribution (T&D) system is usually treated in two sub parts, 1) Primary T&D and 2) secondary T&D. The primary transmission line carries the high current voltage

supply usually of 132KV, 220 KV, 500KV or an even greater amount is spread by three phase overhead wire to the load center. The receiving load center's or sub-station's forwarding supply is called the Secondary and is a transmission line, where the voltage level is scaled down by step-down transformer to 33KV, 66KV, and 135KV. This stepped down supply is then handed over to the primary distribution stations. It is then distributed through overhead 3 phase lines with their respective usage areas such as large scale Industrial, commercial areas where they usually step up or down the supply as per their requirements. Whereas, the supply for residential utilization is transmitted to local sub-stations which is known as Secondary Distribution transmission where it is further stepped-down to 400V in three phase supply over four wires. In which, any single phase wire carrying 200V to 220V and 400V load between any two phase.

The government and public sector companies are the main energy supplier. The government suppliers include the local generation as well the imported energy ratio from other countries. The primary supply is utilized in various power plant operations and a specific ratio of energy is consumed by industrial work like conversion of energy and refining process. In the next Step, private companies add their energy capacity to the system where it passes through the refining process. In third stage, it is transmuted to service provider companies, who are accountable for energy distribution, its billing, and monitoring. While the unit price rates buying and selling, duties and subsidies purely govern by government authorities**[16]**.

The whole process and supply distribution from power generation to consumption is unidirectional which means that there is no control and monitoring capability to manage end to end supply, its uses and consumption. It is fully electro-mechanical grids network with few sensors, zero fault tolerance, manual recovery, check and maintenance. It is the huge and complex networks of transformers, overhead lines, cables and other equipment. This system also does not have the storage system to store power and transmit in peak time as per demand. This means that the power is gained from the generation station on real time as required or per consumption.

### A. *Structure of Energy & Power Sector*

In a broad view, Pakistan power sector is distributed and operated by two major entities. One is Government sector and other are private companies. These entities are responsible to generate, distribute, retail and supply electricity utility to end users. Whereas, with respect to the power generation, Water and Power Development Authority (WAPDA) & IPPs supply electricity to all over Pakistan except Karachi where K-electric supply electricity to Karachi region and its shrouding areas[17]. At present, there are more than 20 private power companies that operate in Pakistan and most of the them contribute by adding their generation capacity to national grid to achieve demand requirement. Figure 2 shows the power sector structural breakdown which helps to understand their role in management, maintenance, operation and implementation of power policy[4].

Public sector or government is the largest component of the system in the supply chain distribution and energy sector policy making. The National Electricity and Power Regulation Authority (NEPRA) and Oil and Gas Regulatory Authority (OGRA) have great influence on market and hold rights to enforce rules, regulations and reforming laws.

### B. *Power Capacity, Supply and Demand*

According to the regression analysis performed in 2008, in a normal scenario, electricity demand will increase by annual ratio of 8% between 2008 to 2030[18]. During last five years, it has been noticed that the demand for electricity increases by about 6-8% annually[19]. The supervision and planning of power generation authorities are not up to mark to overcome the crisis. Also, the maladministration of power sector companies fails to counter the T&D distribution problems which causes a depletion of large amount of energy. The following Table-1 shows the year wise electricity Capacity, Generation, Supply, Demand and T&D Loss.

Where I.C, M.D, S.E, T.S, T&D are the Installed Capacity, Maximum Demand, System Energy, Transmission Supply and Transmission & Distribution loss recorded by the National Transmission and Dispatch Company (NTDC) respectively. Whereas, C.D is the Calculated Difference of installed capacity between to two successive years. Which shows the additional capacity added to the system.

Documents do not contain the statistics of Non-Technical Losses (NTL) of each year, neither the actual or estimated NTL ratio of each year found during the research. Although different statistics are available on different newspaper's, blogs, forums, and other websites for same year, however they seem to be unauthentic and are not included in this research as fact.

A considerable amount of energy is wasted during the transmission and distribution process of electricity supply. The world bank standard for T&D loss allows only about 10 to 15 percent of transmitted energy[2]. Whereas, the stats of T&D showed in above Table is relatively too high than the standard set by the World bank.

### C. *Natural Resources*

Pakistan is blessed with enormous natural & energy power resources such as Water, Wind, Coal, Solar, Minerals, Terrain across the country[2][7]. It is also capable of producing the required amount of energy. The former GM Planning of WAPDA Mr. Nisar Ahmad Bazmi stating "it is an incorrect perception that existing transmission system cannot handle more electricity. The same transmission line can hold 30,000 mw load with a little more investment in the existing system"[27]. The following Figure 3 shows the number of existing location of power plant including Hydro, Thermal and Nuclear energy resources in different region of Pakistan.

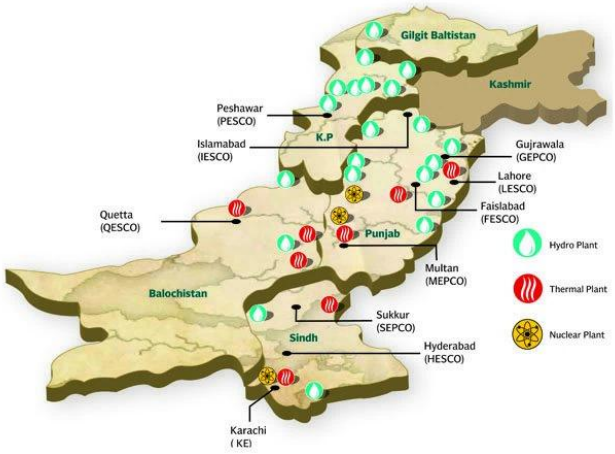


**Fig. 2 Power Resources in Pakistan[28]**

Whereas, from the Table-2, it can easily be identified that energy production is heavily relying on Oil, Gas, and Hydropower, while only relatively small amount of other energy sources such as Nuclear, Coal, Wind contribute in the system. Pakistan energy production is highly reliant on Oil fuel and the ratio in energy production increases every year. The dependency on oil fuel, impose on importing a significant amount of petroleum products which rises import bill to US$ 15 billion in financial year 2013. On contrary, the national company OGDCL express alarming situation regarding Oil resource reservation. According to the OGDCL, Oil resource will be ended by year 2025.

### D. *Recent & Undergoes Projects*

The main concern of new energy policy is to generate more energy. Under new power policy, large number of power will be added to the system. Several projects are in progress and many are planned to build by the end of year 2030 to capture the supply demand gap and capable of fulfill requirement of country. According to the economic survey 2015-16, under Private Power and Infrastructure Board (PPIB), private power sector companies in progress of 27 new power projects of oil, coal, gas, and hydel. These will be capable to produce 15,852 MW by 2024. Pakistan Atomic Energy Commission (PAEC) actively in development new nuclear power plants in different region of nation with plan to acquire 8,800 MW capacity by 2030. Also, the Alternative Energy Development Board (AEDB) in perusing of many Alternative and Renewable Energy (ARE) power projects with the help and interest of private investors. Under AEDB, 27 wind power project are undergoing of the capacity 1347.4 MW with aim to accomplished by 2018, and 28 Solar power project capacity of about 956.52 MW are planned. In China-Pakistan Economic Corridor (CPEC) pact under "Early Harvest" scheme in initial stage 16 power projects of different energy sources are planned to build by year 2018 having capacity of 10,400 MW to aid system[29].

Furthermore, PPIB listed 31 upcoming projects including some CPAC projects with the total capacity of about 19209MW. The scheduled distributions of projects are as; 6 projects of 4907MW by 2017 by, 6 project of 2503MW by 2018, 3 project of 595MW by 2019, 5 projects of 4370MW by 2020, 2 projects of 1450MW by 2021, 8 projects of 2692MW by 2022, 2 projects of 1474MW by 2023 and 3 projects of 1218MW by end of 2024[30]. The Water and Power Secretary, Mr. Younus stated that LNG Balloki Power Plant and nine other are under constructions, which are equip with new technology and will be capable of producing 11000MW by the end of 2018 and it is assume that this will not only eliminate the load-

**Table II**
**PAKISTAN ENERGY MIX OF LAST 6 YEARS**

| | | | ENERGY GENERATION BY SOURCES IN % | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Ref** | **Year** | **I.C (MW)** | **Oil** | **Gas** | **Hydro** | **Nuclear** | **Coal** | **Wind** | **Import** |
| **[20]** | 2015 | 24,906 | 35.52 | 23.52 | 33.41 | 5.13 | 0.11 | 0.47 | 1.85 |
| **[21]** | 2014 | 24,953 | 35.55 | 23.93 | 33.88 | 4.63 | 0.12 | 0.28 | 1.61 |
| **[22]** | 2013 | 23,617 | 36.66 | 24.72 | 34.02 | 4.12 | 0.04 | 0.01 | 0.42 |
| **[23]** | 2012 | 23,246 | 35.82 | 26.93 | 31.92 | 4.92 | 0.07 | 0.01 | 0.33 |
| **[24]** | 2011 | 24,173 | 30.50 | 33.15 | 33.33 | 2.85 | 0.16 | - | - |
| **[25]** | 2010 | 22,263 | 30.50 | 33.15 | 33.33 | 2.85 | 0.16 | - | - |

shading from Pakistan but also have excess amount of energy[31]. According to the source, if everything goes smoothly Pakistan will have the capacity of 34500MW by year 2022[32].

## III. LIMITATIONS

### A. *One Way Communication*

The one-way communication is the major and critical problem of current electric system. This means that the power generation has no check and balance on energy loss and its consumption. The current structure design is to produce energy in bulk quantity and feed all the power to consumer lines through grid transmission. The structure is lacking and unable to respond to the energy demand; how many legitimate users it has, where is power emission occurring, and how much power is actually required and consumed[33][34].

### B. *Zero-Monitoring*

The present electrical system has no monitoring mechanism on its resource utilization and hence, requires more human efforts and workforce to monitor any irregular changes and activities. In this massive electrical network, it seems to be impossible to keep an eye on each and every single user, distribution point and supply line to take action against it in timely manner.

### C. *Zero Faults tolerance*

The current operational electrical grid and power distribution structures are not equipped with any type of fault tolerance capabilities. The structure is not friendly to deal with any sort of disturbance such as high-voltage, overloading, load balancing, and others faults. The system, either goes down immediately or transmits the high supply to the end-user which results in damage and burnout the electrical appliances or grid station.

### D. *Manual Reporting*

The system is not facilitating any event that rises due to high-voltage, electrical overloading and any internal or external influences either natural or malicious activity. It is unable to identify any problem and it is considered that the system is working accordingly, unless the incident is reported.

### E. *Manual Checking & Maintenance*

In the absence of any surveillance system, authorities always require periodical manual checking and maintenance of the power system. This process is time costly and is usually based on patrolling route or pattern to examine power stations regardless of the circumstance and sensitivity of power station. From small to critical problem, manual checking usually results in electricity shut down. In some circumstances it is impossible to work on power stations such like in rainy and other conditions, routine checking and system maintenance are either postponed to the next schedule or next feasible day. This sometimes create an alarming situation and results in disaster at station[35].

## IV. VULNERABILITIES

### A. *Direct Connection to Transmission Line or Kunda System*

Due to the unmanageable and un-monitoring supply system, it unwillingly offers room for easy supply theft. Most of the electricity used in low profile areas, small businesses and as well in some high rank areas are gaining through direct connections, also known as “Kunda System”. These kunda or direct hook connections steal electricity by attaching metal hooks to transmission lines and causes energy emission, bypassing the need for a meter, which lead the demand shortfall and also damage power sector companies[36].

### B. *Meter Tempering*

A very common type of electric theft identified in traditional electric system is bypassing meter which is done by shorting the input and output terminal of electric meter to bypass the metering record. This is done with no efforts and easily plugin and out as whenever needed and meter seem to be work fine no one is able to detect the electric lost and who is steeling it. Another similar way to control the metering and silently mugging the electricity with no evidence by injecting external element into the meter to manipulate and slow down reading at any time either remotely and physically or manually adjusting the circulating speed. Unfortunately, this kind of shoplifting avoid external monitoring and inspection raid as meter is always in running state and shows its working fine with correct metering stats[37].

There are many other ways of meter tempering and electricity stealing by which one can easily access electricity without exposing theft and no billing or adjustable meter limit techniques. These includes mechanical shock to meter[38], power lines tapping[39], Electricity Panel Board and Reversing Meter[36], digital meter hacking by using electrical device demonstrate in [40][41][42], Kill-A-Watt device to slowing down digital meter[43], partial bypass, separate neutral point, trap steel methods[44], reversing magnetic disc and current tampering[45] and about 10 – 12 methods are discussed in[46].

Therefore, in the present system, customer billing is either based on meter reading taken by person, on average on previous billing record if reading not taken or if meter does not show any reading then it will charge as minimum which is consider as no utilization of electricity at all.

### C. *Extensive T&D loss*

Every year, Pakistan's energy sector bears a massive loss of energy. This loss occurs during transmission and distribution processes which cannot be billed or charged to customer. Experts and professionals stated that this huge loss arises due electrical emission in equipment's connection, conductors, devices, resistance of transmission cable. Also the low quality materials, lose joint, long transmission lines, inadequate conductor size, imbalance load, infeasible size of transformer, low power factors, fluctuation, irregular supply and bad circuitry[47]**.** The following Figure-6 shows the T&D loss of net generation supply since year 2008.

**TABLE III**
**T&D LOSS OF NET GENERATION SINCE 2008[4]**

| Year | Net Loss in % |
|---|---|
| 2008 | 21.3 |
| 2009 | 21.1 |
| 2010 | 20.9 |
| 2011 | 20.9 |
| 2012 | 20.6 |
| 2013 | 20.4 |
| 2014 | 20.1 |
| 2015 | 20.2 |

## V. CONSEQUENCES

### A. *Electricity Loss & Cost*

All the above mentioned types of theft and energy mugging have ruthless impact on power sector companies which turns as electricity crisis. The following Figure 4 demonstrate the electric supply theft and bear distribution loss in different power sectors of country during past five years, from 2008 to 2013 recorded as 90 billion rupees[48].

**Table IV**
**Cost of Electricity Theft since 2008 to 2013**

| Company | Loss in Billion PKR |
|---|---|
| KE | 59 |
| PEPCO | 16.17 |
| HESCO | 7.47 |
| SEPCO | 3.6 |
| MEPCO | 0.28 |
| LESCO | 2.35 |
| GEPCO | 0.36 |
| FESCO | 0.6 |
| **Total Loss** | **89.83** |

### B. *Circular Debt*

When the supplied amount of energy does not result in the expected receivable amount of money, a supplier entity suffers the cash inflow problem to release financial obligations to its suppliers and withholds its payments to them. This insufficient revenue collection disturbs the whole payment chain and one company becomes defaulter of the other. These troubles are primarily caused by high electricity theft ratio and unpaid bills[49][50]. Due to insufficient funds and circular debts, public and private power sector companies drop down the power production because they are not sure about the electric dues and future loss whereas the demand arises very frequently. Unfortunately, the supply remains constant at its level or scale down if dues increase[51]. Pakistan is bearing a gigantic amount of uncontrollable circular debt which not only increases by every year but damages the power sector companies' performance. The annual circular debt since year 2008 to 2015 express in the Figure-8[27][48][49].

**TABLE V**
**CIRCULAR DEBT, SINCE 2008 IN BILLION DOLLARS**

| Year | Circular Debts |
|---|---|
| 2008 | 198.8 |
| 2009 | 228.6 |
| 2010 | 204.2 |
| 2011 | 285.8 |
| 2012 | 385.6 |
| 2013 | 411 |
| 2014 | 512.9 |
| 2015 | 603.1 |
| 2016 (Aug) | 684 |

### C. *Electricity Shortfall & Effect on GDP*

Although the current power generation capacity is about 24,906MW as of June 2016, the country is still suffering from the energy shortage and demand gap of about 5000MW that causes daily 5 to 6 hours of load-shading and about 2.5-3% yearly estimated shed on GDP[54]. High electricity theft and large amount of circular debt are obstacles for power companies to produce the right amount within limited resources. Even though, Pakistan always been capable of producing the maximum electricity demand as shown in above Table-1. Due to the vulnerabilities of system and rapidly increasing dues resulted in electricity shortfall[51]. Figure-5 shows that the capacity and the total power produced by the existing plants against the total power required. It is clear evidence there is never been load shading exist in country but improvement of electric system to control theft and better administration[55].

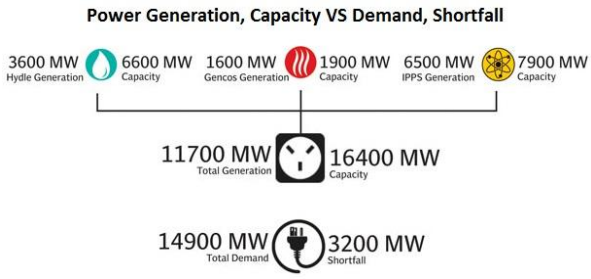


**Fig. 3 Power Generation, Capacity VS Demand & Shortfall[55]**

### D. *Price*

When the energy producing, and distributing companies are unable to overcome their dues, expenditure of development and expansion plant capacity. Ultimately, regulating authorities enforce to increase electricity utility charges which is the preferable option for defaulter companies to pay off their dues with the small production.

### E. *Street Crime*

It has been observed that the only group which feels more feasibility and take advantage of load-shading or electricity shortfall in the country is criminal. The darkness facilitates the criminal activist to harm and rob people, shops and business offices without being fear of anything. As security system get powered off, people are unable to recognize them and law enforcement officials unable to peruse them. The Punjab Police IG stated that load-shading is responsible for rapid increasing crime rate[56]. Another news reported that 40% rise in crime due to the electricity blackout[57], [58].

## VI. CHALLENGES

The existing power crisis divides into the four classes Governance and Management Issues, Policy Issues, Technical Issues and the most important Cost Issue. Among all four categories, the influence of utility price is the highest concern of authorities and has direct impact on other three groups. Some of the major issues of above groups are listed as under.

**Table VI**
**Challenges of power sector companies**

| Ref | Challenges |
|---|---|
| **[59]** | Requires proper check and balance of Power plants are operation and their efficiency |
| | improve distribution services |
| **[6][49][59] [60] [61]** | Reduce the electricity price |
| **[49]** | Energy conservation and demand management |
| **[49]** | Reduce the circular debt overhanging and prevent from recurrence |
| **[49]** | Improve the energy sector performance |
| **[49]** | Reforming new policies |
| **[49][61]** | Replacing aging power plants and component |
| **[6]** | Overcome the demand supply gap and adding more capacity to system |
| **[6]** | Promoting and moving toward renewable energy sources. |
| **[6]** | Improve transmission and distribution system to reduce T&D loss |
| **[61]** | Reduce power theft |
| **[61]** | Improvement in billing recovery |

## VII. RESEARCH FACTS

The research underlines few but valuable points that massively hit the routine life, barrier in furnishing better society and environment. The facts are not only limited to the above few but primarily damaging the backbone which resulted in all such interconnecting problems of country. These facts are as under;

- System is aging and incompetent
- Plants need proper maintenance, check and balance on regular/routine basis.
- Power policy not equally importance other factors then of generation.
- Poor administration and politically ill environment
- *Poor conducting material, old hardware and over long transmission causes transmission & diminution lines not following the standards in all region of country.*
- *Uncontrollable and undetectable supply theft.*

Studies shows, among all above, the two highlighted points are the root causes that challenge in managing other causes and leading to problems such as T&D loss, energy theft, short circuit at sub-stations, feeder and transformers, irregular and uncontrolled supply, electricity shortfall or crisis, unwanted circular debt, higher energy utility tariff, fewer resources for power generation, damaging distributing services, less industrial production, unemployment, business loss & closure fear, hosting crime, and decreasing GPD.

## VIII. CONCLUSION

The rising energy situation in Pakistan getting critical and by passage of time it will cost billions of dollars' surplus every year. The negligence of govern body in energy sector makes it worst, while the unstoppable demand frequently rising with the urbanization and developmental actives and services. Although, the existing system and the installed energy capacity is more than enough to fulfil the require supply demand of country. However, there is a need to replace the aging system, plants and hardware which is not much efficient to properly supply transmission. A very huge ratio of energy supply is wasted during transmission and other

dominating factor is unnoticeable supply theft. These lead several chain and core problems of country, such as circular debt among supply and distributer companies, less energy production, electricity shortfall, high energy utility tariff and more importantly decreasing GPD among many others problems. This is an alarming condition for country to mitigate these standing issues. As todays, almost every single activity of life is dependent on adequate availability of energy, either is about house hold activities, personal, education, social, economic, business, industrial or development to advance civilization and stand side by side with fast moving world.

Adding more and more power to the system is not a suitable and reliable solution to deal with the energy crisis and its linking effects on other sectors but the need to cater the future demand gap. Research observed that more addition to ailing system results in more loss and wastage in power generation and transmission services. Whereas, apparently the decreasing numerical percentage of electricity loss comparatively seem to be better and improvement of system. But, on contrary, the fact is opposed by the figures. Such as, by year 2015 stats show that system identified loss is 19.87%, which in number are 19,364 GWh, while in the year 2009 stats shows system identified loss is 22.63%, which in number are 19,091 GWh. The clear calculated difference between 6 years' duration is still higher than of 270GWh energy loss and the installed power capacity added to the system during these years is about 4254MW which is about 15340GWh energy.

Identified root causes of energy crisis and its financial burden on country, will be useful in future work and study that promptly resolve energy related issues.

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## REFERENCES

[1] Safiya Aftab, "Pakistan's energy crisis: causes, consequences and possible remedies," 2014.

[2] F. Hayat and D. Pirzada, "Prevailing Energy Crisis in Pakistan," *Mech. Energy, Environ.*, pp. 251–258, 2011.

[3] M. K. Arshad and U. Ahmed, "Energy demand in Pakistan: a disaggregrate analysis," *Mpra*, no. 15056, pp. 437–455, 2009.

[4] S. Khan and H. F. Ashraf, "Analysis of Pakistan ' s Electric Power Sector," 2015.

[5] R. N. Lodhi and R. K. Malik, "Impact of Electricity Shortage on Daily Routines: A Case Study of Pakistan," *Energy Environ.*, vol. 24, no. 5, pp. 701–710, Oct. 2013.

[6] KCCI., *Energy scenario in transport.pdf*, vol. 14. KCCI, 2013.

[7] M. Kugelman, "Pakistan's Energy Crisis From Conundrum to Catastrophe?," *NBR Comment.*, pp. 1–7, 2013.

[8] ICCI, "An Overview of Electricity Sector In Pakistan," 2013.

[9] A. N. Khan, T. Begum, and M. Sher, "Energy Crisis in Pakistan : Causes and Consequences," *Abasyn J. Soc. Sci.*, vol. 4, no. 2, pp. 341–363, 2010.

[10] S. Khalid, "SAARC Study Assessment of Energy Efficiency Potential through Energy Audit of Power Transmission and Distribution Grid Stations in Pakistan December 2014 SAARC Energy Centre , Islamabad," 2014.

[11] Jie Zhou, "Summary of Smart Grid Presentation," *ifcedc.blogspot*, 28-Jul-2011. [Online]. Available: http://ifcedc.blogspot.com/2011/07/summary-of-smart-grid-presentation.html. [Accessed: 04-Jan-2017].

[12] "Power Generation - Power to the People." [Online]. Available: http://www.prsenl.com/energy/traditional-electricity/traditional-electricity-webpages/power-generation/. [Accessed: 04-Jan-2017].

[13] "Electrical Grid - EnergyGroove.net." [Online]. Available: http://www.energygroove.net/technologies/electrical-grid/. [Accessed: 03-Jan-2017].

[14] "Typical AC Power Supply system scheme and Elements of Distribution System." [Online]. Available: http://www.electricaltechnology.org/2013/05/typical-ac-power-supply-system-scheme.html. [Accessed: 29-Dec-2016].

[15] "Transmission Grid - Power to the People." [Online]. Available: http://www.prsenl.com/energy/traditional-electricity/traditional-electricity-webpages/transmission-grid/. [Accessed: 05-Jan-2017].

[16] S. Ejaz Wasti, "Energy," in *Pakistan Economic Survey 2013-14*, 2014.

[17] PPIB, "PAKISTAN POWER SECTOR PLAYERS." [Online]. Available: http://www.ppib.gov.pk/N_fpse.htm. [Accessed: 05-Jan-2017].

[18] "ELECTRICITY DEMAND FORECAST Based On Regression Analysis (Period 2008 to 2030)," 2008.

[19] BOI, "Power & Energy," *Board of Invesment*, 2012. [Online]. Available: http://boi.gov.pk/Sector/SectorDetail.aspx?sid=2.

[20] NTDC, *POWER SYSTEM STATISTICS 2014-2015*, 40th ed. NTCD, 2015.

[21] NTDC, *POWER SYSTEM STATISTICS 2013-2014*, 39th ed. NTCD, 2014.

[22] NTDC, *POWER SYSTEM STATISTICS 2012-2013*, 38th ed. NTDC, 2013.

[23] NTDC, *POWER SYSTEM STATISTICS 2011-2012*, 37th ed. NTDC, 2012.

[24] NTDC, *POWER SYSTEM STATISTICS 2011 June*, 36th ed. 2011.

[25] NTDC, *POWER SYSTEM STATISTICS 2010 June*, 35th ed. NTDC, 2010.

[26] NTDC, "Power Data Reference Book Nov 2010- July 2016," *Power Plan. NTDC*, vol. 2, no. 1, pp. 1–328, 2016.

[27] J. Rizvi, "Demystifying Pakistan's Energy Crisis," 2015. [Online]. Available: http://www.technologyreview.pk/demystifying-pakistans-energy-crisis/. [Accessed: 08-Dec-2016].

[28] Spearhead Research, "Burden of power: Why we are in the dark – Spearhead Research – Pakistan," 2015. [Online]. Available: http://spearheadresearch.org/index.php/economyenergy/burden-of-power-why-we-are-in-the-dark. [Accessed: 06-Jan-2017].

[29] S. Ejaz Wasti, "Energy," in *Economic Survey of Pakistan 2015-16*, 2016th ed., Ministry of Finance - MoF, 2016, pp. 238–277.

[30] "Upcoming Power Projects of IPPs," 2016. [Online]. Available: http://www.ppib.gov.pk/N_upcoming_ipps.htm. [Accessed: 08-Jan-2017].
[31] "Pakistan's most efficient power plant to be operational in 2017 | Pakistan Today," 2016. [Online]. Available: http://www.pakistantoday.com.pk/2016/09/23/pakistans-most-efficient-power-plant-under-construction-will-be-operational-in-2017-water-and-power-secretary/. [Accessed: 08-Jan-2017].
[32] M.A Zuberi, "A Map Of Upcoming Power Projects In Pakistan Power Sector Future." [Online]. Available: http://lahorecafe.pk/map/a-map-of-upcoming-power-projects-in-pakistan-power-sector-future/. [Accessed: 06-Jan-2017].
[33] Barbara Wichmann, "The Pros and Cons of Smart Grid Technology," 2014. [Online]. Available: http://artemia.com/the-pros-and-cons-of-smart-grid-technology/. [Accessed: 08-Jan-2017].
[34] "Rethinking the Electric Grid." [Online]. Available: http://www.thegabi.com/renewable/article/139. [Accessed: 08-Jan-2017].
[35] R. Jain, "Smart Grid: Trends in Power Market." .
[36] Z. Hussain, S. Memon, R. Shah, A. Bhutto, M. Aljawarneh, and Z. Hussain, "Methods and Techniques of Electricity Thieving in Pakistan," *J. Power Energy Eng.*, vol. 4, no. 4, pp. 1–10, 2016.
[37] "Theft of electricity," *WekiPedia*. [Online]. Available: https://en.wikipedia.org/w/index.php?title=Special:Book&bookcmd=download&collection_id=5fcf2759f34919c5cf04e5466c4b2705c4789cd7&writer=rdf2latex&return_to=Theft+of+electricity. [Accessed: 08-Jan-2017].
[38] B. Saikiran and R. Hariharan, "Review of methods of power theft in Power System," *Int. J. Sci. Eng. Res.*, vol. 5, no. 11, 2014.
[39] S. E. Distribution, "Electricity Theft Control with Real-time Billing Framework utilizing Information Communication Technologies." pp. 1–10, 2013.
[40] "ETHERTEK SOLUTIONS: HOW TO HACK A DIGITAL ELECTRICITY METER." [Online]. Available: http://www.ethertekug.com/2014/02/how-to-hack-digital-electricity-meter.html. [Accessed: 23-Dec-2016].
[41] "how to hack electric digital meter in pakistan and cut your electricity bill in half - YouTube." [Online]. Available: https://www.youtube.com/watch?v=9tMv49Pg8rA. [Accessed: 23-Dec-2016].
[42] "Stop Power Meter Pakistani Electricity Meter - YouTube." [Online]. Available: https://www.youtube.com/watch?v=GW8aw61z2t4. [Accessed: 08-Jan-2017].
[43] "Lower your electricity bill with the Kill-A-Watt device - YouTube." [Online]. Available: https://www.youtube.com/watch?v=vNXWMro672g. [Accessed: 08-Jan-2017].
[44] M. Bin Sarfaraz, "Power Theft Detection | Energy Central." [Online]. Available: http://www.energycentral.com/c/pip/power-theft-detection.
[45] Ingenuity Dias, "Tampering Electricity Meter-Commonly used Tampering Techniques-Science Tips and Tricks | IngenuityDias," 2014. [Online]. Available: http://www.ingenuitydias.com/2014/12/tampering-electricity-meter-commonly.html. [Accessed: 23-Dec-2016].
[46] Jignesh Parmar, "Tampering Methods of Energy Meter | Electrical Notes & Articles," 2011. [Online]. Available: https://electricalnotes.wordpress.com/2011/06/08/tampering-methods-of-energy-meter/. [Accessed: 23-Dec-2016].
[47] Jignesh Parmar, "Total Losses in Power Distribution &; Transmission Lines-Part 1," 2013. [Online]. Available: https://electricalnotes.wordpress.com/2013/07/01/total-losses-in-power-distribution-transmission-lines-part-1/. [Accessed: 08-Jan-2017].
[48] "Herald: Gridlocked – how power is lost in Pakistan's distribution lines - Pakistan - DAWN.COM." [Online]. Available: http://www.dawn.com/news/1159359. [Accessed: 29-Dec-2016].
[49] R. Shoukat, "Pakistan Energy Crisis: An Overview," 2013.
[50] F. Mahmood, M. Assistant, and S. Mahmood, "Long Run Determinants of Electricity Theft in Pakistan: An Empirical Analysis Muhammad Saim Hashmi," *Pakistan J. Soc. Sci.*, vol. 35, no. 2, pp. 599–608, 2015.
[51] F. B. Lewis, "Costly 'Throw-Ups': Electricity Theft and Power Disruptions," *Electr. J.*, vol. 28, no. 7, pp. 118–135, 2015.
[52] "Power sector circular debt surpasses Rs684 billion: IWCCI." [Online]. Available: http://www.thefrontierpost.com/article/404966/power-sector-circular-debt-surpasses-rs684-billion-iwcci/. [Accessed: 22-Jan-2017].
[53] "Power sector circular debt surpasses Rs684b." [Online]. Available: http://nation.com.pk/business/29-Aug-2016/power-sector-circular-debt-surpasses-rs684b. [Accessed: 22-Jan-2017].
[54] "Energy Sector Projects under CPEC," *pakchina.pk*, 2016. [Online]. Available: http://pakchina.pk/energy-sector-projects-cpec/. [Accessed: 06-Jan-2017].
[55] Zafar Bhutta, "Why we are in the dark - The Express Tribune." [Online]. Available: http://tribune.com.pk/story/704228/burden-of-power-why-we-are-in-the-dark/. [Accessed: 08-Jan-2017].
[56] "IG blames loadshedding for Punjab crimes - Pakistan - Dunya News." [Online]. Available: http://dunyanews.tv/en/Pakistan/121996-IG-blames-loadshedding-for-Punjab-crimes-. [Accessed: 09-Jan-2017].
[57] "Power outages: Energy crisis linked to rising crime in Punjab's industrial heartland - The Express Tribune." [Online]. Available: http://tribune.com.pk/story/317702/power-outages-energy-crisis-linked-to-rising-crime-in-punjabs-industrial-heartland/. [Accessed: 09-Jan-2017].
[58] "Attock: Power riots death toll reaches 2 – Pakistan Criminal Records." [Online]. Available: http://pakistancriminalrecords.com/2010/08/20/attock-power-riots-death-toll-reaches-2/. [Accessed: 09-Jan-2017].
[59] G. Maaz Mufti, M. Jamil, M. Nawaz, Mobeen-ur-Rehman, S. Zulqadar Hassan, and T. Kamal, "Evaluating the Issues and Challenges in Context of the Energy Crisis of Pakistan," *Indian J. Sci. Technol.*, vol. 9, no. 36, 2016.
[60] R. Aziz and M. B. Ahmad, "SPECIAL REPORT: Pakistan's Power Crisis - The Way Forward," 2015.
[61] M. Anwar and S. Rehman, Eds., "Solutions for Energy Crisis in Pakistan," in *Solutions for Energy Crisis in Pakistan*, 2013, pp. 1–258.