International Journal of Industrial Engineering and Management (IJIEM), Vol. 6 No 3, 2015, pp. 133-142
Available online at www.iim.ftn.uns.ac.rs/ijiem_journal.php
ISSN 2217-2661

UDK: 005:620.9(540)

Affect of Disruptive Energy Supply to Different Type of Industrial and Business Players: An Overview of Concepts and Review of Studies from India

Harjit Singh Mangat
Ph.D. Research Scholar, Punjab Technical University, Kaputhala, Punjab, India
(Assistant Professor, Department of Mechanical Engineering, Baba Banda Singh Bahadur Engineering College, Fatehgarh Sahib, Punjab, India, mangat84@gmail.com)

Harpuneet Singh
(Assistant Professor, Department of Production Engineering, Guru Nanak Dev Engineering College, Punjab, India, prof.harpuneetsingh@gmail.com)

Received (16.12.2014); Revised (13.05.2015); Accepted (17.09.2015)

Abstract

An outage is registered whenever the electricity is completely interrupted for a minute or longer. It frequently takes place during a storm or after an accident when power lines are damaged. At other times, power may be off for quite a few days. From time to time the power company turns off the electricity to an area to save power for 1 to 2 hours at a time. The electricity is returned and after that turned off to another area. Time is money for every industrial as well as business player. Even a brief downtime thrive a wave of tension on the shop floor and ultimately put a blow on the profits of industrial and business players. Electricity plays an essential role in modern society, bringing benefits and progress to industrial, commercial, agricultural and residential sectors. For all human activities, electric power is vital for economic growth and quality of life. Terms and factors which can affect the electricity network and interrupt customers' supply will be conferred in detail. An endeavor has been made to thoroughly review and discuss the various key definitions, terms and concepts associated to power system reliability. An in depth effort has been carried out to discuss the various causes of power outages. A review of key studies from India related to the impact of power outages on different businesses and industries is done which reveals that economic impacts from these are immense and hence affect the economy of the nation.

Key words: *Business Sectors, Customers, Economic growth, Electric power, Power outage*

1. INTRODUCTION

In the short extent of two centuries, Electricity has become an indispensible part of present day life. Electricity plays an essential role in present modern civilization, providing benefits and development in diverse fields, including health and medicine, transportation, manufacturing and communication technologies. Work, leisure, healthcare, economy and livelihood can be seriously hampered without a constant supply of electrical power. The availability of production system for a maximum time is the primary objective to establish and maintain a respectable position among the highly competitive industrial and business players.In an epoch where execution of businesses is unimaginable in the absence of electrical power, even a short-lived power outage can cause relative chaos and remarkable losses of productivity, material and revenues. The level of blow caused by a power outage to an individual business varies by industry and the nature of applications. It can vary from being disruptive to life threatening. Power outages bring production lines to an unexpected arrest. This possibly will render into material loss, machine breakdown and loss of industrious productive time. Power outages can be especially disastrous when it comes to life-support systems in places like hospitals and nursing homes or in co-ordination conveniences such as in airports, train stations, and traffic control. Whilst a loss of power in smaller scale settings may perhaps not be life frightening but it can result in data loss, missed deadlines, productivity or revenue loss. Luckily most life support conveniences have a source of backup power that is ready to automatically take over the load when the main power grid fails. Backup power is also increasingly being used in company conveniences, manufacturing, mining, businesses and even residential houses as the reliance on electronics and computers in our daily lives increases.

2. CONCEPT OF POWER OUTAGE

The total loss of electric power on, at least, one normally energized conductor to one or more customers

connected to the distribution portion of the system is called an “outage”. It is the result of one or more component outages, depending on system configuration. The loss of ability of a component to deliver power is called an “outage”. An outage is registered whenever the electricity is completely interrupted for a minute or longer. Electrical power outages can happen at any time. The time period from the initiation of an interruption until service has been restored to the affected customers is called outage duration [1]. Power outages frequently arise during a natural catastrophe or after an accident when power lines are broken. The power companies try to get the electric power back as early as possible. At other times, power may be off for numerous days. Sometimes the power companies switch off the electricity to a vicinity to bank power for one to two hours at a time. The power is restored and then switched off to another region. This is called a rolling blackout. The electricity is typically turned off during times of elevated use. The power companies try to give warning before turning off power to a region. An electricity distributor can’t guarantee for the continuous power supply because the power system can never be 100 percent reliable. Some outages are unavoidable since portions of the network are exposed to events beyond the reasonable control, like storms and vehicle accidents. For some customers, a short power outage may perhaps be a mere hassle but for others, a power disruption may possibly cause commercial losses. It is essential to respond as quickly as possible to fix any supply problems in order to prevent the after-effects which would be very disruptive if not prevented. It is also important to understand and consider the level of risk associated with an occasional interruption to electricity supply [2].

2.1 **Key Definitions, Terms and Concepts associated to Power System Reliability**

The concept of power system reliability i.e. the overall capability of the system to assure the customer load requirements cost-effectively and reliably is tremendously wide. Power system reliability has been categorized into system adequacy and system security. Adequacy associates to the survival of adequate facilities within the system to assure customer load demands. These comprise the conveniences to generate power and the related transmission and distribution facilities required to transfer the generated energy to the load points. Thus, Adequacy relates to static system conditions. Security pertains to the response of the system to the disturbances it is subjected to. These may incorporate conditions linked with local and widespread disturbances and loss of major generation/transmission. The definition of Reliability has been approved by Operating Committee and Planning Committee of NERC (North American Electric Reliability Corporation) in December 2007. NERC had used the term “security” until September 2001. But when security became synonymous with homeland protection in general and critical infrastructure protection specifically, NERC reinstate that name with “operating reliability.” Operating reliability is not a definition in the NERC Glossary of Terms but instead is a reliability concept. “Adequacy” is the capability of the electric system to supply the aggregate electric power and energy requirements of the electricity consumers continuously, considering planned and reasonably expected unplanned outages of system components. “Operating reliability” is the capability of the electric system to withstand sudden disturbances such as electric short circuits or unanticipated loss of system components. Most of the techniques presently available are in the domain of adequacy assessment. The terms and factors which can affect the Electricity network and interrupt customers' supply are explained as follows:

2.1.1 *Planned Outages*:

The intentional disabling of a component’s capability to deliver power, done at a pre-selected time, usually for the purposes of construction, preventative maintenance, or repair. A planned outage arises when electrical lines or equipment have to be temporarily taken out of service for repair or to allow network maintenance and alterations.
A planned outage will be scheduled in advance and affected customers will be made alert of the outage before it arises. Every endeavor is made to carry out planned outages during times which will cause least hassle to customers however in some occasions this is not at all times feasible [3,4].

2.1.2 *Unplanned Outages:*

The loss of electric power to one or more customers that does not result from a planned outage. The second type of power interruption is an unplanned outage. It is a consequence of the loss of a section of the network due to a fault, which can include: equipment failure, cable faults, damage by third parties, lightning strikes, high winds, pole fires, trees or branch interference, bird or animal interference etc. In these situations, there is no possibility of giving customers an early warning of an approaching outage. [3,4].

2.1.3 *Blackouts:*

Blackouts come devoid of warning, last for indefinite periods and are usually caused by tragic equipment failure or severe weather. The nature and source of the blackout decides who is affected [5].
A blackout refers to a complete loss of a power to a geographic area and is the most severe form of power outage that occurs. A blackout power failure can last a few minutes to a few weeks, depending on the severity and nature of the underlying cause of the power cut.
Depending on the root cause of the blackout, bringing back power is a very difficult task that utilities and power stations must undertake and repair timeframes vary greatly depending on the configuration of the affected electrical network. Power Cuts or Blackouts usually take a considerable amount of time to locate the source of the trouble, repair the trouble and then bring back power back to residences [6].

2.1.4 *Rolling Blackout/Power Rationing/Load Shedding:*

Planned outages and rolling blackouts differ slightly in that planned outages are usually announced well in advance and are most commonly needed to allow for schedule maintenance, while rolling blackouts can arise with comparatively little warning and are intended to take stress off of the system's energy load [5]. Load shedding can be required when there is an inequality between electricity demand (customers' usage) and electricity supply (the ability of the electricity network to generate and transport the required amount of electricity to meet this demand). To relieve the burden on themselves and their consumers, providers may begin to share electricity. The flow of electricity is discontinued in one area for a predetermined amount of time. Then, supplies are reconnected in that region and disconnected somewhere else. In several cases people in the affected regions, especially the businesses that are dependent on power are notified in advance. For firms in the manufacturing sector, this implies that they cannot run their machinery and therefore cannot produce [7].

2.1.5 *Brownouts:*

Brownouts are deliberately produced by energy providers as an emergency measure to prevent the system from failing completely (blacking out). Usually, a utility will reduce system voltage by 10-25%, usually for a short span of time. This decrease characteristically has smallest effect on heat and lighting systems, the majority of that can function consistently for short periods on suboptimal voltage however sensitive electronic equipment requiring reasonably precise voltages may not be able to function and long-term brownouts can cause premature wear in non-electronic devices. Computer disk drives frequently experience write failures when supplied with suboptimal voltage and electric motors be liable to run hotter while required to produce the same horsepower during a brownout [5]. Brownouts are reduced line voltage for extended periods of time, like days or weeks. An intentional reduction in power for conservation or extremely heavy loads causes brownouts. A brownout is a fall in the electrical power supply. It is so called as it leads to a fall in voltage and causes lights to turn out to be dim. Even though brownouts are not whole power failures but they can badly affect electrical equipment. Induction and three-phase electrical motors are especially at risk during a brownout, as they can overheat and their insulation can get spoiled. If the main power supply is unpredictable and experience repeated brownouts, then consideration should be given to investment in a backup power system that will automatically take over and provide equipment with the necessary power when the voltage drops. A brownout is a steady lower voltage state. An illustration of a brownout is what takes place during peak electrical demand in the summer, when utilities can't at all times meet the requirements and must lower the voltage to limit highest power. As soon as this occurs, systems can experience glitches, data loss and equipment failure. Feasible solutions are the use of Voltage Regulators, Uninterruptable Power Supplies, and Power Conditioners [6].

2.1.6 *Power Surges:*

Voltage surges/spikes are the opposite of dips: a rise that may be nearly instantaneous (spike) or takes place over a longer duration (surge). A voltage surge takes place when the voltage is 110% or more beyond usual. The most widespread reason is heavy electrical equipment being turned off. Under these circumstances, computer systems and other high tech equipment can experience flickering lights, equipment shutoff, errors or memory loss. Likely solutions are the use of surge suppressors, voltage regulators, uninterruptable power supplies, power conditioners [6]. These are most often caused by lightning strikes and arcing during switching operations on circuit breakers/contactors (fault clearance, circuit switching, especially switch off of inductive loads) [8]. Power surges are the bane of any power system. A power surge can direct to fast overheating and loss of critical and costly equipment. Luckily, safeguard from such surges is available in the form of surge protectors and circuits breakers. Surge safeguard must ideally be incorporated into the main power switchboard itself. Smaller setups, that have a limited number of critical pieces of equipment can opt to employ portable surge safeguard devices that plug in to the power grid [9,10].

2.1.7 *Electrical trees:*

Electrical treeing is an event that affects high power installation such as high voltage transformers and power cables etc. Some impurities /mechanical defects in the equipment used in high voltage installations can lead to partial electric discharges in the equipment. The destructive process manifests itself in a tree-like pattern and thus the name electrical treeing. Over a span of time, if it goes unobserved, this event can lead to an incessant degradation of the equipment and ultimately result in a total breakdown. In order to fight against electrical treeing, it is essential to utilize high quality materials that are designed to handle the electric load. Regular maintenance executed by trained engineers can also help to identify and rectify electrical treeing before it can cause a major breakdown [11].

2.1.8 *Short Circuits:*

A short circuit is the most commonly used term to depict the reason of a power failure. A short circuit occurs when an electric current travels along a path that is different from the anticipated one in an electrical circuit. When this occurs, there is an extreme electric current which can lead to circuit damage, fire and explosion. Indeed, short circuits are one of the primary causes of electrical fires throughout the world. Short circuits can take place when the insulation of the wiring used breaks down. It can also take place due to the existence of an external conducting material (e.g. water) that is introduced accidently into the circuit. Electrical batteries can blow up if they are subjected to a huge current. Short circuits can still take place when electric motors are forced to operate when the moving parts are stuck.

This leads to anomalous increase of current, eventually leading to a short circuit. Some ways to safeguard electrical systems from the hazards are discussed here. First and prime, make sure that all the equipment that is used in your electrical installation is composed of good quality materials and meets the correct specification for your application. The preliminary installation costs may perhaps be higher than a system made with cheaper materials but the savings you will make in avoiding potential losses caused by short circuits and maintenance can be considerable not to reveal the additional safety and peace of mind you get. Wires should always be of the highest quality and of the correct gauge for your application. It must also be remembered that wires and other electrical circuits should never be overloaded. Electrical overload results in overheating; causing the insulation to break down, that consecutively can direct to a short circuit. Pistons, rotors, pumps and other moving parts of an electric motor should be regularly serviced and checked to make sure that there is not any jamming. High-class fuses, circuit breakers and other overload safeguard devices must be installed so that power can be immediately disconnected in the event of a short circuit, thus averting injury to sensitive equipment. While exploiting circuit breakers, it is also essential to pick circuit breakers of the correct rating. It must make certain that all bare circuits are kept covered and protected from moisture. Electric power is critical to society and business alike. Weather is responsible for the majority of major power outages that take place but as evidenced above there's plenty more than just weather that should be accounted for when designing an power system. Finally for the preeminent promising safeguard, always install a backup power generator as a way to make definite multiple levels of backup are in place [11].

2.2 **Classification of Voltage Events depending on the severity and duration of the variation in voltage**

Different standards define a voltage event in a different way. IEC 61000-4-30:2008 defines interruptions, voltage dips and swells as a deviation in Root Mean Square (RMS) voltage below 10%, below 90% and above 110% of the nominal or a sliding reference voltage, respectively. As per IEC 61000-4-30:2008, one voltage event might have more than one classification. IEEE Std. 1159:1995 categorized voltage events as interruptions, dips or swells based on their spot in the magnitude-duration plane, after first determining the magnitude and duration of the event but cannot have more than one type of classification. The LabVIEW Electrical Power Suite acquires voltage events data in compliance with *IEC 61000-4-30:2008.* A change in voltage causes a decrease or an increase in the amount of energy supplied to components in an electrical power system, which leads to an amount of energy that is different from the amount required for usual operations. A decline in energy during a voltage dip can cause equipment to reset or shut down and cause mechanical devices, like motors, to stall or overheat. A boost in voltage during a voltage swell can cause immediate or long-term breakdown of components as of overheating. Since the voltage level during a voltage interruption rapidly decay to zero, or to nearly zero, no energy is transmitted to components in an electrical power system when there are voltage interruptions. A voltage interruption hence might cause the complete shutdown of equipment and also may lead to damage. A voltage interruption over a huge geographical area that lasts for a long term is called a blackout. Depending on the severity and duration of the deviation in voltage, one can categorize voltage events as follows: Voltage dips, Voltage swells and Voltage interruptions.

2.2.1 *Voltage Sag/Dip:*

A short duration drop in voltage is called Sag. A decrease of the normal voltage level between 10 and 90% of the nominal r.m.s voltage at the power frequency for periods of zero, 5 cycle to 1 minute. Power Sags, which are periods of short-term low voltage activity, caused by the startup of large loads. Most appliances will continue to function normally, however lights may perhaps dim momentarily and television pictures may, for a moment, shrink slightly [9,10]. Faults on an electrical power system cause voltage dips. For instance, a short circuit can cause voltage dips. A short circuit generates a huge current to flow those results in a fall in the voltage across system loads. Since the amount of energy that a component draws is proportional to the square of the current, a short circuit too causes a hefty flow of energy through a component that may possibly damage the component. Short circuits are typically the consequence of an insulation breakdown or an overvoltage caused by switching operations or lightning strikes [12]. Some possible causes are as follows: Faults on the electric delivery system caused by accidental damage, animal contact or tree interference i.e. Faults on the transmission or distribution network (most of the times on parallel feeders); Faults in consumer's installation; Connection of heavy loads and start-up of large motors; Start-up of large appliances; More sensitive equipment could be more noticeably affected; Malfunction of information technology equipment, namely microprocessor-based control systems e.g. Personal Computers, Programmer Logic Controllers, etc. that may well lead to a process stoppage; Tripping of contactors and electromechanical relays; Disconnection and loss of efficiency in electric rotating machines. Some possible mitigation measures are as follows Connect computers and other sensitive electronic devices to circuits other than the ones your large motor-driven appliances are on; try to lighten the load on the affected circuit [14,15].

2.2.2 *Voltage swells:*

Momentary increase of the voltage, at the power frequency, outside the normal tolerances, with period of more than one cycle and usually less than a few seconds [10]. A voltage swell is a boost in the RMS voltage above the nominal voltage or a sliding reference

voltage. The increase lasts from half a cycle to several seconds [12]. Various causes are as follows: Start/stop of heavy loads; badly dimensioned power sources; badly regulated transformers (mainly during off-peak hours); capacitor banks energizing; transfer of loads from one power source to another. Some of the serious consequences due to swells are data loss, flickering of lighting and screens, stoppage or damage of sensitive equipment, if the voltage values are too elevated [10].

2.2.3 *Voltage Interruptions:*

A voltage interruption is a big decrease in RMS voltage to less than a small percentile of the nominal voltage or an entire loss of voltage. Voltage interruptions may come from accidents like faults and component breakdowns or from planned downtime. Short voltage interruptions are typically the result of a malfunction of a switching device or a deliberate or inadvertent function of a fuse, recloser or circuit breaker, in reply to faults and disturbances. Long interruptions are generally the consequence of planned downtime, where part of an electrical power system is disconnected in order to perform maintenance or repairs [12,13].

3. COMMON CAUSES OF POWER OUTAGES

There are many factors that can lead to Power Outage such as system overload, short circuit, faults at power grid, damage at power source and others including extreme weather conditions like snowstorms, hailstorms, rainstorms, hurricanes, tornadoes and other natural calamities. It is crucial to know about the possible causes of power failure so as to effectively defend business from its caustic effects [11,16]. The root of an outage is not always obvious or immediately evident. Some of the possible causes of power failure are discussed below:

3.1 **Natural Causes - Weather Related**

The Edison Electric Institute states that 70% of power outages in the U.S. are weather related. Several power outages are caused by natural weather phenomena such as lightening, rain, snow, ice, wind, and even dust. It's sometimes impossible to defend major power outages from natural calamities like floods and severe storms. But it's quite easy to prevent electrical systems from the effects of water and dust. Water can lead to short circuits and power outage. Electrical switchboards, wires and circuits should be protected from exposure to water. Humidity and excessive moisture can also lead to severe damages. The investment must be made in specially sealed circuit protection devices if the residence falls in areas having high levels of humidity. Dust can also ruin chaos with electrical power systems and lead to short circuits and power outages. A special attention must be paid to the location of electrical circuits if a residence falls in an area that is exposed to sandstorms and it should be confined from dust exposure as much as possible. Sealed circuit boxes can also help in shielding significant electrical equipment and can aid in avoiding unplanned power outages. Natural catastrophes have been the root cause of the world's most ruthless power outages. Hurricanes, floods, wind storms, earthquakes, tsunamis and other brutal weather can utterly demolish significant electric power infrastructure and result in outages that leave many geographic regions without power for days, weeks, and even months [11].

3.2 **Other Causes of Outages**

The Edison Electric Institute study also indicates that animals coming into contact with power lines, such as large birds, accounted for 11% of outages in the U.S. Additional causes of failures were primarily man made outages that show up in the form of vehicle and construction accidents with power poles and lines, repairs from utilities and the infrequent human error [11].

4. INFLUENCE OF POWER OUTAGES ON DIFFERENT BUSINESS SECTORS

Other some of the major industries and business functions that are severely hampered by power failures are as follows:

a) *Manufacturing Firms*: Power outages bring production lines to an abrupt halt. This may interpret into loss of material, collapse of machinery and loss of productive time. This results in delayed deliveries and may cause supply chains to push down altogether. Manufacturing companies are heavily dependent on power for fully-automated production and assembly lines. Everything from packing, filling and labeling to quality control is accomplished by machine. Men have a diminishing role. Every minute the power is out will cost the manufacturing plant in terms of profits. For food and beverage companies, a power outage can also result in entire batches of products being discarded- an expensive practice. In a inferior case, a power outage can cause machinery to breakdown, which might widen the profit loss for days or weeks to come [17].

b) *Financial Corporations:* When an electric power goes off during the working hours in stock market, it will leads to big loss of money within few seconds. In an industry where huge money can be made in profit within a fraction of a second, power outages render financial corporation's unable to accomplish vital transactions on time. This is identical with lakhs-crores of unrecoverable rupees per minute of downtime followed by several extra hours of recovery time. Power outages cause disorder in the stock market, paralyzing trading and thereby refusing investors, stockbrokers and regulators the opportunity of making money [17].

c) *Consulting and Information Technology (IT) Services:* Consulting businesses and IT firms are highly dependent on computers, the internet and endless connectivity to provide services to customers. These firms and software development facilities have hundreds of highly paid experts. Even a short-lived outage leaves them trapped and

d) outcomes in loss of billable hours. In an epoch where IT operations are firm's connectivity to the entire world, power outages result in crashed computer systems, lost data and rapid execution of communications with customers. This is frequently followed by numerous weeks of endeavor used up in recreating hundreds of man-hours of work. Programs and data may possibly get corrupted ensuing in software recovery operations that may not be resolved for weeks [17].

e) *Data Centers:* Data centers are the spine of operations for several firms such as financial and information technology (IT) services firms, insurance companies etc. An irrecoverable loss of thousands of records stored over the years and interruption in ongoing transactions can be caused by power outages. From retail to banking, IT systems are significant to the operation of many businesses and behind these IT systems is a vigorous data centre. A data centre is a committed space where firms can keep and operate most of the ICT infrastructure that supports their business: servers and storage equipment that run application software and websites, processing and storage data and content etc. So, if a power outage takes place it is a blow not only for the data centre provider but for the hundreds of customers who are dependent on them [17].

f) *Perishable stuff:* Petrochemical, Food processing and Pharmaceutical industries rely heavily on continuous availability of power for storage and preservation of perishables that have tremendously limited life spans without the right temperature storage conditions. Power outages can cause in-process material worth several lacs to be discarded due to damage, spoilage or contamination. When the power to a domestic refrigerator goes off, a household can lose hundreds of rupees of food and groceries [17].

g) *Control Centers:* Traffic signal functions, transport systems such as railways, air traffic management, telecommunications & utilities control centers, depends greatly on continuous power supply for smooth functioning. Disturbance in such critical operations can jeopardize the safety and security of lacs of unsuspecting consumers in a moment. A power outage can impact the transportation scheduling (resulting in delays and cancellations) but also put commuters at risk [17].

h) *Medical and Health Conveniences:* In hospitals, patients' lives are precisely maintained by health monitoring systems. Any discontinuity in the usual functioning of medical equipment can directly interpret into loss of many lives. It goes without saying that hospitals and surgeries are severely impacted by electric power outages [17].

i) *Military Operations:* Power outages render expensive equipment, weaponry and even workforce, unguarded, and thus, divulging them to the possibility of attack. These days' military operations are heavily dependent on intelligence. As a result, an electric power outage can result in a loss of valuable and confidential information, while also exposing them to risk of cyber attack. Electric power outages can leads to downtime for telephones, computers, lights and critical systems [17].

j) *Entertainment Venues:* Cancellation of money-spinning events even for short-lived period of time equates to massive losses of revenue for entertainment facilities. In addition to resulting in losses of revenues, sudden termination of regular operations can also become harmful to visitors and operating personnel as well. This also led to security problems for personnel and patrons, because thieves take benefit of the dark surroundings [17].

k) *Safety and Security:* In addition to causing hassle, power outages can endanger the safety of the common man. Power outages can cause buildings to shut down, elevator troubles, darkness, safety cameras stopping to function, dead telephone lines, and numerous additional troubles that can put people at risk. These are just a few examples of power outages becoming more than just an annoyance factor and menacing to endanger the safety and lives of lacs of people simultaneously [17].

4.1 **Review of studies showing the impact of power outages on business sector in India**

A very few studies pertaining to power system reliability were conducted in India. A few of them are discussed in depth under this section.

4.1.1 *Nexant SARI/Energy, USA*

In 2003 Nexant SARI/Energy prepared a report on "Economic Impact of Poor Power Quality on Industry: Review of Studies" for USAID-SARI/Energy Program and the outcomes of the study are stated here in brief. The results of the research done by Dr Krishna Rao in 1999 suggested that the power shortages existing in different states of India during the period 1970-90 had a significant negative impact on the average rate of growth per capita income. The results suggest that a 10% shortage of power supply during the 1970s has reduced the average growth rate of per capita income approximately by 0.1% whereas the same 10% shortage in power supplies in the 1980s reduced the average per capita income growth by 0.5%. TERI- The Energy and Resources Institute Report on "Cost of Unserved Energy" revealed that lack in the availability of electric power to the manufacturing sector resulted in loss of value added (GDP) to the level 1% and 2.2% of the overall manufacturing sector value added (GDP) in the States of Haryana and Karnataka respectively, for the year 1998-99. A sample of about 1,054 industrial consumers and 1,800 agricultural consumers was utilized for gathering primary data, using a pre-tested questionnaire. The data was related to the year 1998-

99. The report also indicated that for the same period, lack in the availability of power to the agricultural sector resulted in loss of value added (GDP) to the level 3.1% and 13.3% of the overall agricultural sector value added (GDP) in the States of Haryana and Karnataka respectively. The real position of power supply in India as on March 2002 indicated that, at the collective level, electric power consumers in India face power shortages to the level of 12.6% in peak power (kVA) availability and to the level of 7.5% in energy (kWh) availability. It was apparent that India's GDP and GDP growth rate would persist to be adversely influenced in future. One other supplementary but important finding of the TERI study is that, for the sample of industries studied (about 1,054), the cost of self generation is across the board lower than the tariff charged by the respective state electricity boards. It was found that no widespread study on the economic impact of poor power quality and/or power shortages either on the economy as a whole or on specific sectors and /or sub-sectors exists for India, it was recommended that such a study be carried out for India [18].

4.1.2 *FICCI, India*

In 2012, Bureau of Research on Industry and Economic Fundamentals through Federation of Indian Chambers of Commerce and Industry (FICCI) conducted survey across major 25 cities to understand the ways of tackling the frequent power cuts being faced by Indian Industry. A total of 650 firms representing both the manufacturing as well as service group were targeted for the study. The random samples were selected from the Large, Medium and Small Business enterprises. The results revealed that around 37 percent of firms, mainly in Gujarat, Maharashtra and Karnataka face less than 1 hour of power shortage in a week and at the same time 5 percent suffer 21-30 hours per week and 21 percent suffer more than 30 hours per week (primarily in Tamil Nadu and Andhra Pradesh). It has also been evident from the study that 16 percent face 6-10 hours of power shortage per week, while 15 percent face a power shortage between 1-5 hours weekly. This in itself gives a concise idea of the impact of the current power scenario in India and on the Indian industry [17].
The survey also revealed that 54% of companies were aware in advance of the load-shedding schedule and the information is available. Within the 46%, the majority of companies that did not know the schedule were from particular states. This implies that stakeholders in certain states are hence unprepared for power failures, raising the negative impact of electric power outages on their operations. Firms in Andhra Pradesh, Odisha and Tamil Nadu have revealed the highest impacts due to the poor power supply situation. On the other hand, states like Gujarat, Karnataka and Maharashtra have continuously shown the least impact on companies operating within these states. As observed, the revenue losses due to power outage range between less than Rs. 1000 to higher than Rs 40000. Even small and medium firms incur losses exceeding Rs. 40000, primarily in the inferior performing states. The comparison of losses due to planned and unplanned power cuts for states such as Andhra Pradesh, Tamil Nadu and Odisha exposed that losses due to planned power cuts were less than Rs.10000 for majority of the firms as compared to losses due to unplanned power cuts which are above Rs. 10000 for the majority and above Rs. 40000 for few. Losses due to voltage fluctuations were as low as Rs. 1000 for states like Karnataka and Maharashtra and as high as Rs. 40000 for Andhra Pradesh, Tamil Nadu and Odisha. No voltage fluctuations were observed in Gujarat and Delhi NCR region [19].

4.1.3 *International Energy Agency (OECD/IEA 2012), Partner Country Series, France*

IEA prepared a report on "Understanding Energy Challenges in India Policies, Players and Issues" and the outcomes of the study are discussed here in brief. In the middle of 2012, India's power shortage led to substantial rolling power cuts across the nation. Industries and businesses were shut down and followed by public protests demanding better power supply. India's energy sector is increasingly unable to deliver a protected supply of energy amid growing demand and fuel imports. Two major trends become visible in India's overall energy sector: first, a severe energy shortage across different fuel sectors, ranging from coal, gas, and oil to uranium. The scarcity of these fuels is resulting in a significant shortage of electricity, which hinders economic and social development. Second, there is a rising need to import more energy as a result of the country's stagnating domestic production. Crude oil used to be the main energy import, but India now needs to import bigger volumes of coal and gas as well. However, due to considerable inequality between domestic and international prices for these fuels, actual imports might not take place, or will take place to a lesser degree than the actual fuel shortage might require. Furthermore, rising fuel imports will have negative implications on India's financial situation. To well address these two trends, India wishes a functioning energy market. There are six main challenges that need to be addressed to create a well-functioning and financially-viable energy market in India:

- The core capabilities of players in India's energy sector should be improved.
- Pricing mechanisms in the energy sector should ensure commercial feasibility and send proper signals to the market.
- India needs considerable investment to meet up its growing energy demand and provide access to all citizens.
- An increase in effective execution of energy policies is required.
- Truly integrated and consistent energy policy is critical.
- Sturdy political will is a precondition to effectively cope with energy sector challenges.

As the father of India's nuclear energy, Dr. Bhabha, once put, "no power is as expensive as no power." A reliable and ample delivery of modern and clean energy is the requirement for India's continued economic

development. Nothing would be more costly than the interruption of the national economy, which has so much prospective to thrive, as well as the interruption of daily activities of the Indian citizens, who are ready to participate in another economic wonder. To complete the conversion of India's energy sector into an open and functioning energy market, the country necessitates strong political leadership to pass on clear policy messages. In the context of an increasing need for investments and the integration of India's energy sector into the global energy market, India needs to ally its energy policies and institutions with global practices [20].

4.1.4 *Mangat and Singh (2013)*

Mangat and Singh (2013) found that considerable attention has been directed throughout the world to assess the economic consequences to electric energy customers due to unreliable electricity supply. Due to intricacy in cost patterns of industrial sector in comparison with residential and commercial sector, very little studies were carried out in this sector. So, three Craft paper mills of medium scale in Ludhiana (Punjab) were selected as a practical case to conduct a study considering the years 2008 and 2009. Customer survey approach was adopted as the customer is in the best position to assess the effects of interruptions or outages and thus give help to calculate associated costs more accurately. The primary purpose of conducting this survey was to establish monetary losses associated with weekly off-days and peak load imposed by electricity board in 2008 and 2009. The number of weekly off-days and peak load (Load Shedding) was analyzed accurately through circulars available on the official website of Punjab State electricity Board. The analytical results show that an outage loss over these two years considering a market value of Craft Paper for Paper mill-A was Rs 10948201.4 for weekly off days and Rs 8575378 for peak load. Similarly, an outage loss for Paper mill-B was Rs Rs 5022541 for weekly off days and Rs 4580434 for peak load and for Paper mill-C it was Rs 320349.98 for planned outages, Rs 6257532 for weekly off days and Rs 4613448 for peak load.The approach called Customer Damage Function (CDF) was used in this study. It includes two terms, one that ascribes a cost to the energy not supplied in Rs/kWh and one that ascribes a cost to the load disconnected. CDF was calculated for three paper mills which portray the costs associated with outages as a function of outage duration. It has been observed that customer damage function values were maximum for Harisar Paper Mill followed by H.B Papers Pvt. Ltd and Champion Paper Mill This is the first ever study on Paper mills in Ludhiana using customer survey approach [21]

4.1.5 *Allcott et al. (2014)*

Allcott et al. (2014) concluded that India's lack of reliable electricity supply provides a bare example of how poor infrastructure affects economic growth. A hybrid Leontief/Cobb-Douglas production function model has been developed to shed light on the different ways in which input shortages affect firms and use simulations to validate and extend the empirical results. An affect of planned "power holidays" on daily production at large Indian textile plants were examined, using data from Bloom et al. (2013). The short-run effects of electricity shortages on Indian manufacturing firms between 1992 and 2010 were also studied, using archival data on shortages, previously-unavailable panel data and an instrument for shortages based on variation in hydro reservoir inflows. A productivity effects are smaller: due to small share of electricity costs, high-cost self generation increases energy costs by only about 0.15 to 0.5 percent of revenues and since most inputs can be stock up during outages, the productivity loss is only a portion of the output loss. Three main conclusions were derived from the study. First, electricity shortages are a large drag on Indian manufacturing, on the order of five percent of output. Secondly, electricity shortages affect productivity much less than output. Thirdly, shortages have diverse effects across firms with versus without generators and with high versus low electric intensity. It has also been observed that because of economies of scale in self-generation, small firms are less liable to own generators, meaning that shortages have higher negative effects on small plants. This study used a static model, spotting on the effects of annual variation in shortages with fixed capital stock [22].

5. CONCLUSION AND RECOMMENDATIONS

An endeavor has been made to review the various key concepts and few studies related to power system reliability. Various possible causes of power outages are conferred in detail. It has been concluded from the review that almost all business sectors around the world are affected very badly by the power outages. A very few studies in India were conducted measuring the negative impacts of unreliable power. In 2003, Nexant SARI/Energy, USA conducted a study measuring the economic impact of power quality on industrial sector in India. This study showed how GDP is negatively impacted by unreliable power and hence the economy of the nation. In 2012, FICCI, India also conducted a survey measuring the impact of power outages, voltage fluctuations, load shedding on different industrial sectors across 25 cities from all over India. It has been specifically observed in India that a very modest endeavor has been made in this research field. In the recent years, only few studies pertaining to the impact of power interruptions on industrial sector and its effect on power system reliability were conducted. This research area though been developed to considerable altitude in agriculture, commercial and residential sector but a lot more is needed to explore the stuff in industrial sector since not much sincerity has been shown in this sector. Due to a complexity of cost patterns occurring in the industrial sector and long time span required for conducting a study using questionnaires and schedules, a very few people has shown interest in this field, especially in India. Everyone is aware of the condition of power systems in India. The pace of development in power sector is very slow. Industries are still dependent

on age old power systems and are suffering from high cost of production due to unreliable power since power outages forces the industrial consumers to use diesel generators in order to compete all around. It's the high time to shift from traditional sources of energy towards the renewable sources of energy. An effort must also be done to promote more sophisticated energy efficient systems coupled with green energy to prevent the environment. An endeavor should also be taken to save energy with some mitigation strategies i.e. Cogeneration in industrial firms.

6. REFERENCES

[1] IEEE Power Engineering Society, IEEE Std 1366-2012; Revision of IEEE Std 1366-2003 (May 31, 2012), "*IEEE Guide for Electric Power Distribution Reliability Indices",* Institute of Electrical and Electronics Engineers, Inc., New York.

[2] Wellington Electricity Lines Limited, New Zealand (2009), *"Power Outages Explained"* available at: http://www.welectricity.co.nz/power_outages/Pages/default.aspx (accessed: 11 January 2014).

[3] Wellington Electricity Lines Limited, New Zealand (2009), *"Causes of Power Outages"* available at: http://www.welectricity.co.nz/power_outages/Pages/causes.aspx (accessed: 11 January 2014).

[4] IEEE Std 762™-2006 (2006), *"IEEE Standard Definitions for Use in Reporting Electric Generating Unit Reliability, Availability, and Productivity (ANSI)",* Power System Analysis, Computing and Economics Committee of the IEEE Power Engineering Society, Institute of Electrical and Electronics Engineers, Inc., USA.

[5] Energy Dictionary, "blackout, brownout, brown power, rolling blackout" available at: http://www.energyvortex.com/energydictionary/EnergyVortex.htm#blackout__brownout__brown_power__rolling_blackout.html (accessed: 11 January 2014).

[6] Rojin, R.K. (2013), *"A Review of Power Quality Problems and Solutions in Electrical Power System",* International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 2, No. 11, pp. 5605-5614.

[7] Sing'andu, N. (2009), "*An Assessment of Impact of ZESSCO's Power Rationing on Firm Productivity and Profitability: A Case of Selected Luaska Based Manufacturing Firms"*, Master Thesis, School of Business of Copperbelt University, Zambia.

[8] Agarwal, A., Kumar, S. and Ali, S. (2012), "*A Research Review of Power Quality Problems in Electrical Power System",* MIT International Journal of Electrical and Instrumentation Engineering, Vol. 2 No. 2, pp. 88-93.

[9] Khalid, S. and Dwivedi, B. (2011), *"Power Quality Issues, Problems, Standards and Their Effects in Industry with Corrective Means,* International Journal of Advances in Engineering & Technology, Vol. 1 No. 2, pp. 1-11.

[10] Deshmukh, S.M., Dewani, B. and Gawande, S.P. (2013), *"A Review of Power Quality Problems-Voltage Sags for Different Faults*", International Journal of Scientific Engineering and Technology, Vol. 2 No. 5, pp. 392-397.

[11] Diesel Service and Supply (2013), *"The Many Causes of Power Failures"* available at: http://www.dieselserviceandsupply.com/Causes_of_Power_Failures.aspx (accessed: 11 January 2014).

[12] NI Systems (India) Private Limited (2012), *"Voltage Dips, Swells, and Interruptions, Electrical Power Suite, LabVIEW 2012 Electrical Power Suite Help,"* available at: http://zone.ni.com/reference/en-XX/help/373375B-01/lveptconcepts/ep_dip_swell/ (accessed: 11 January 2014).

[13] IEEE Std. 1159™-2009 (2009), "*IEEE Recommended Practice on Monitoring Electric Power Quality",* Transmission and Distribution Committee of the IEEE Power & Energy Society, Institute of Electrical and Electronics Engineers, Inc., USA.

[14] Zhang, L.D. and Bollen, M.H.J. (1999), *"A Method for Characterization of Three-Phase Unbalanced Dips (Sags) from Recorded Voltage Wave Shapes",* Proceedings of International Telecommunications Energy Conference (INTELEC), Copenhagen, 1999.

[15] Zhang, L.D. and Bollen, M.H.J. (1998), *"A Method for Characterizing Unbalanced Voltage Dips (Sags) with Symmetrical Components",* IEEE Power Engineering Review, Vol. 18, pp. 50–52.

[16] Western Power (2014), *"common causes of power interruptions"* available at: http://www.westernpower.com.au/customerservice/interruptionsrestoration/commoncausespowerinterruptions.html (accessed: 11 January 2014).

[17] Diesel Service and Supply (2013), *"Top 10 industries that would be affected most by a power outage"* available at: http://www.dieselserviceandsupply.com/Industry_Power_Outages.aspx (accessed: 11 January 2014).

[18] Nexant SARI/Energy (2003), *"Economic Impact of Poor Power Quality on Industry: Review of Studies",* United States Agency for International Development under South Asia Regional Initiative for Energy, USA.

[19] Bureau of Research on Industry & Economic Fundamentals (2012), *"Lack of Affordable and Quality Power: Shackling India's Growth Story",* Federation of Indian Chambers of Commerce & Industry, New Delhi.

[20] Ahn, S.J. and Graczyk, D. (2012), *"Understanding Energy Challenges in India Policies, Players and Issues",* International Energy Agency (OECD/IEA 2012), Partner Country Series, France.

[21] Mangat, H.S. and Singh, H. (2013), *"Impact of Long Duration Planned Outages on Paper Mills: A Comparative Study of Three Paper Mills", International* Journal of Computer and Electrical Engineering, Vol. 5 No. 5, pp. 505-510.

[22] Allcott, H., Wexler, A.C. and O'Connell, S.D. (2014), *"How Do Electricity Shortages Affect Productivity? Evidence from India",* Working Paper, New York University, USA.

Uticaj prekida dostave električne energije na različite grupe industrijskih i poslovnih korisnika: Pregled koncepata i analiza studija iz Indije

Harjit Singh Mangat, Harpuneet Singh

Primljen (16.12.2014); Recenziran (13.05.2015); Prihvaćen (17.09.2015)

Rezime

Prekid struje se registruje kad god je električna energija u potpunosti u prekidu minut ili duže. Često se dešava tokom oluje ili nakon nesreće kada su oštećeni dalekovodi. U drugim slučajevima, struja može da bude isključena i po nekoliko dana. S vremena na vreme elektrane isključe dovod električne energije na neko područje kako bi štedili energiju na sat ili dva. Električna energija se uključi i nakon toga isključi na nekom drugom području. Vreme je novac za svakog industrijskog, kao i svakog poslovnog korisnika. Čak i kratak zastoj razvija talas napetosti u poslovnom prostoru i na kraju predstavlja udarac na profit industrijskih i poslovnih korisnika. Električna energija igra veoma važnu ulogu u modernom društvu, donoseći napredak i prosperitet industrijskim, komercijalnim, poljoprivrednim i stambenim sektorima. Za sve ljudske aktivnosti, električna energija je važna za ekonomski rast i kvalitet života. Uslovi i faktori koji mogu da utiču na električnu distributivnu mrežu i prekinu dotok do potrošača biće detaljno istraženi. Rad nastoji da temeljno pregleda i preispita različite ključne definicije, uslove i koncepte povezane sa pouzdanošću sistema distribucije električne energije. Poseban napor je izvršen kako bi se prodiskutovali različiti uzroci obustave električne energije. Urađen je pregled ključnih studija iz Indije povezan sa uticajem obustave električne energije na različite poslove i industrije, otkrivajući da su ekonomske posledice ovoga ogromne i zato utiču na ekonomiju cele nacije.

Ključne reči: *poslovni sektori, potrošači, ekonomski rast, električna energija, nestanak struje*