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## Evaluating the Power Interruption and Managing to reduce Outages

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### ABSTRACT

Generally every power interruption (outage) and lasting it for time impose irretrievable damages. The power outages resulted from natural events or equipments and installations defects and weakness result in irreparable damages to country economic and reputation of power distributor. The power outages in distribution section can be evaluated and analyzed from different aspects. Undoubtedly, the low rate of outage for every power company is considered an advantage and strength. Some companies compete to reduce power outage and define it as one of their main objectives. Therefore it is essential to decrease as possible the power interruptions by helping the human force's experiences and with spending the required costs to stable the networks and by precise programming, services and repairing in time, using adequate devices and equipments and existing facilities. This study in addition to explain the power outages, kinds of it and its effects on different parts, tries to represent the better methods of programming and planning for planned outages and monitor or manage the interruptions.

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## INTRODUCTION

The main duty of distribution companies is to provide the stability of power networks in standard and acceptable level. The various factors such as climate, poor performance of equipments and technical defects cause fault in grid. The fault may result in power outages for consumers. Nowadays, the numbers of sensitive loads required to better services are increasing such automatic lines of factories, melting furnaces, and electronic devices of homes (Abbasali, 2009). Moreover, dependence of routine life to electrical energy caused the power outages in addition to affect adversely on economic, impose grate social and psychological effects. Regard to above factors, the number of outages and duration of restoring them is considered the important evaluating and inspecting indices by power distribution companies (Abbasali, 2009). The different consumers require the different reliability and confidence. Comparing the consumers' experiences of outages with what is occurred in entire system lead to better understanding the function and performance of distribution companies for managing the outages. It is required that the consumers' tolerance in every region and effective factors are identified in order to employ the proper plan and managing unwanted (unplanned) and planned outages. (Abbasali, 2009)

*Types of power outages:*

Power outages are categorized in to two main groups:

*A – Planned (wanted) outages:*

The planned (wanted) outages are planned before and its duration and the related area is determined, mainly they are done to repairs or when there is shortage of power to prevent the more outages of grid.

*B-Unwanted (accidental) outages*

They are occurred accidentally and not predictable. It can be summarized the main reasons of unwanted outages as following:

a – The external disturbances cause accidents and outage such as: hitting the vehicles to power grid. b – Weather disturbances: flood, storm, snow and etc. c – Defect of installed equipments or poor quality of installed equipments: insulator and..... d – Aging the grid and equipments. e – Hitting the branches of trees to grid.

f – Imposing the extra load on grid and equipments. g – Lack of in time services of equipments.

h – The role of human force in outages time and reducing the duration of outages (Abbasali, 2009), Faramarz *et al.* (2000)

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*The effects of outages:*

The adverse effects of outages are pre-maturing aging and eroding of equipments especially in transformers, generating in-rush currents. The effects of outage are studied in following cases.

*Influence of outages on electrical machines:*

The small engines are made so that resist against impulses of actuating and can tolerate the less damage. But the big engines require a method to decrease the vibration or current of actuating; otherwise the engine will be damaged greatly. The created damage and fault may influence on the other engines operate in parallel with damaged engine. Therefore it is necessary to employ the proper procedure to reduce as possible the effects resulting from actuating current or vibration. It is noticeable that the repeated outages affect adversely on power generators (Lesani,2011). The mechanical torque is increased by sudden decreasing of load (demand) and this phenomenon cause to increase the speed of generator quickly and the sudden change of speed create shock on axis of generator and grid and until the limited time result in fluctuations of voltage and network frequency. The entered shocks lead to decrease the effective life of generator and other network equipments. (Ahmadiyan, 2009)

*The effect of outages on distribution Transformers:*

Protecting the transformers against types of over voltages, currents of circuit breakers, inrush currents and other faults occurred on grid is essential. Regard to existing all equipments (lightning arrester, CT, PT, high flow relay, differential relay) are employed to protect the transformers, some parameters in order to use the transformers better should be considered. The number of outages affect directly on the operation and useful life of transformers. Because of the power interruption and restoring, the inrush currents are imposed on transformers when the transformers are being powered again that the currents are about 6 times the nominal current of transformers and can last for nearly long time and its amplitude may reach 30 times the nominal current of transformers. The over currents cause to generate heat, damage the insulator ,make the oil of transformer dirty and lead to reduce the useful life of transformer. Also when network is connected again, the phenomenon cold load pick up result in over loads on transformers and damage the transformer windings and because the number of employed transformers in network is great especially in distribution level, therefore the amount of damage of transformers is considerable.(Faramarz *et al.*, 2000), (Abbasali, 2009).

*The effect of outages on power switches:*

The power switch is the main device to connect (switch on) and disconnect (switch off) the power circuits, thus the most effects will be on this device. Certainly the mechanism of switch disconnecting influences directly on its performance. Since the power switch connects and disconnects the circuit under load, there is always sparks in the contacts that the intensity or severity of the sparks depends on the amount of voltage, current, type of load and etc. Sparks cause to spot the contacts, generate heat, decompose the oil, generate gas and create pressure particularly at the time of switching off. The switch loses its function, speed and precision after repeated on and off and may place the stability of grid at risk because of delays in its function. Certainly the modern power switches are able to connect and disconnect the circuit 25000 times, but they require inspecting and repairing annually and servicing completely in order to assure their proper functions especially this should be considered seriously in existing power switches of grid.

*Effects of outages on home appliances:*

Many home appliances lose their normal manner or work for the fluctuations resulted from power on and off and sometimes they are burned out. These problems caused the manufacturer and consumers of the electrical devices use the protective equipments in order to prevent damages as much as possible. However the protective equipments are not able to control completely the damages and losses resulted from circuit connecting and disconnecting. At first glance, it seems the damages of the electrical devices resulted from power outages are not important, but in fact because of the transient states which occurred at the primary times of connecting and disconnecting, it may the devices are damaged seriously and lose their useful life.(Faramarz *et al.*,2000), (Bakamali, 2002),(Abbasali, 2009).

*The effect of outages on industry:*

Since establishing industry and their generating depend directly on continuing electrical feed, every outage or even decreasing the load or electrical fluctuations affect adversely on the equipments and production of factories and sometimes resulted in irreparable damages. Even when the outages are occurred with precede informing of factories, again it creates many problems for production and re-actuating the machineries and cause spending cost, consuming time and setting the machines. As whole, the adverse effects of power outages on industries have the direct relation to production rate and adverse effect on economic of country. (Anbiyae, 2004)

*A-Factors increase the outages duration is categorized into two groups:*

Technical factors

### The basic faults in equipment/equipments:

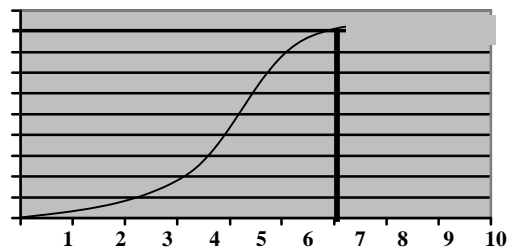
Some outages are not detected until close inspection and reaching to equipments and grid position and the full or partial faults without close inspection can't be identified. It is obvious that restoring the basic faults require consuming much time. The solution to control and reduce the duration of the outages resulted from equipments defects is i- regard to the duration predicted to repair the equipment, the special position of the equipment in the grid is identified. ii- The probability of equipments faults can be calculated in accordance to their life long. When this probability is identified for equipments, their installation place is determined and the basic faults in equipments in sensitive points can be prevented.

$t = R(t)$  the probability of non fault or soundness of system over time.

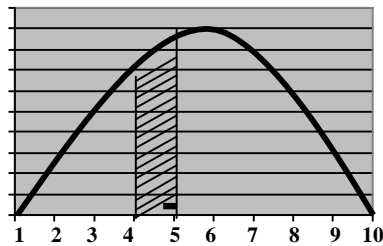
$t = Q(t)$  probability of equipment fault over time.

If we assume zero for the fault probability of new equipment, over the time  $t \rightarrow \infty$  the probability of being fault is increased and the probability of being soundness is decreased according to probability function:

$f(x)$



According to integral in below the curve the probability of equipment life is 4-5 years



Probability for the equipment life is 7 years and less than 7 years

It is assumed that air sectionneurs with 10 years useful life is installed in a position of grid. The probability of switch fault at  $t_0$  time is zero and the fault probability is increased with  $t \rightarrow \infty$ .

$\lambda$  = fault rate

The sound number/ the fault number at time =  $\lambda$

If  $\lambda$  is in steady rate,  $Q = 1 - e^{-\lambda t}$ .

It is supposed that the sectionneurs with 10 years life should be stared and stopped 200 times with no fault, but when 200 times connecting and disconnecting, 40 faults are occurred for sectionneurs. Where

The first fault at time  $t=2$  2 years  $\lambda = 0.2$

The probability of fault or defect at year 2  $Q = 0.32$

The probability of fault or defect at year 4  $Q = 0.77$

It is seen the more life and number of repairs of equipment, the more probability of fault and defect over time exist until there is 90% fault and defect probability at its final life. Therefore the best choice is to replace the equipment.

### The numbers of faulted or defected equipments or the rate of grid that is faulted:

When restoring the fault, the number of the equipments is faulted in distribution network makes important role. Sometimes it is required spending more time than predicted to restore the fault of equipment or faulted bus of the network it means that the fault of an equipment can't depend on a special formula and depends on many parameters. The best method that can be selected is to use probability function. It means that by knowing the production year of the equipment, the probability of fault can be calculated for equipment or equipments. (Bakamali, 2002).

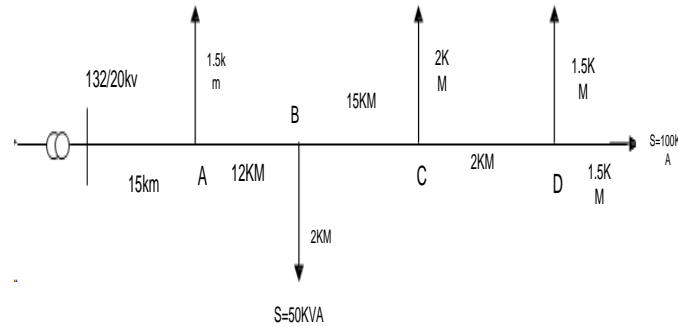
### Limitations of isolating fault from the sound parts of grid:

As a whole, power networks either air or terrestrial networks are subjected to defects and faults. The duration of outage can be reduced by using the fault limiters, automatic detectors and switches at proper position and proportional to critical parameters in considered point. In other word, the total of undistributed energy can be limited to some percentage. When the limiters of current flow are not available easily or absent, the operation group/groups should spend time to isolate the fault part from the sound part. Selecting the position and the numbers of automat and non-automat switches depend on some factors:

- 1- Rate of passing power
- 2- The consumers' sensitivity to continuing flow of power
- 3- Radial or non radial network.

The above factors can be economic justification for the numbers of automat and non automat switches. A network transmits the energy requires inspecting and evaluating the switches are able to off and also automatic protector and its number.

- S=500 KVA
- S= 300 KVA
- S= 200 KVA



It is supposed that there are other desired relational and physical factors and in beginning point, the zero point feeder. When the feeder is disconnected due to a fault in line or equipments and the energy transmitting conducted the total feeder load 1150VA or 1. 5MVA is zero. It is assumed that the fault in this feeder is occurred after point B and it is clear that the load 550 kilovolt ampere (KVA) can be sustained power up and this is when there is automat or non automat switch after point B. Using the limiter and non automatic breaker after point B calls for electrical officer traveling at least 27 kilometers and in the best conditions, 30 minutes is taken to go after point B in order to isolate the fault part from sound part. The undistributed energy at 30 minutes is:

$$W = 30.60 * 0.85 * 550 = 223/75 \text{ KWH}$$

Having a switch after node A can prevent losing 234 KV/h at 30 minutes.

$$850 * 0.85 * 45 / 60 = 541/87$$

required time	Distributed energy	After node
30	234 KWH	B
45	542KWH	C
50	744KWH	D

$$1050 * 0.85 * 50 / 60 = 743/7$$

It is observed that only by having one non-automatic breaker; losing energy can be prevented considerably and outages duration reduced. If there is automat protector after points A, B, C, D, the undistributed energy can be reduced in a short time. Certainly in this chapter the economic discussion for installing auto-Recloser or automatic switch is not followed. If the switches equipped with remote control are employed, in addition to limit the undistributed energy and reduce the outages duration, the area where energy is not distributed can be limited.

*Lack of skill to repair the equipment quickly:*

Generally the great costs have been spent for lack of skill to repair the equipments. (Faramarz *et al.*,2000)

**Strategy:**

- Familiarity with new technology and using accessories.
- Training for installing the equipments
- Practical training to use the equipment and learning the equipment repairing.
- Learning to switch off the switch in short time.

*Unavailable the required parts and equipments:*

Sometimes the created fault of equipments is not significant, but because of non expensive, small and negligible part (component) the duration of outage is increased and when decision is made to provide the part even when the distance is not far, the duration of undistributed energy and as result the undistributed energy is increased. (Lesani, 2011)

If we know the total for availability and unavailability is:

$$P(A) + P(U) = 1$$

$$P(A) = \frac{M}{T} = \frac{\Gamma}{\Gamma + \lambda}$$

$$p(u) = \frac{r}{T} = \frac{\lambda}{\lambda + \Gamma}$$

Fault rate

$$r = \frac{1}{\Gamma}$$

$\Gamma$  = rate of system repairing

It is observed that for the systems follow the exponential distribution; the duration of outages can be reduced and equipments can be available through measuring work time and repairing time in a far area over time and averaging the measured values. .( Anbiyaee, 2004)

*Limitations of making automate and remote controlling the network:*

Making thee network automat result in reducing the duration of outage. For the following reasons the transmitting and distribution networks have not been automated:

- 1 – Interface for distributing and generating
- 2 – Expensive costs of networks and switchboards and necessity to create control center
- 3 – The electrical parameters influence more effect on network stability than the distribution networks that more investments are invested to be networking and automate. But nowadays automating the super distribution networks is attracted more attention following the transmitting networks and control centers of super distribution networks in order to control the network and reduce the duration of outages. The following results obtained by remote control and maneuver of network:

- 1 – To reduce the duration of power interruption or outages and increasing the customers' satisfaction.
- 2 – To reduce the undistributed energy and prevent losing the incomes or revenues of companies.
- 3 – To increase human force empowerment and skills and use the created capacities for other needs.
- 4 – To prevent problems for production lines, industries, agriculture and etc.
- 5 – Prevent human force leaving their work in production line (protecting capital).
- 6 – When the outages of a big consumer are prevented, the network stability will be increased. However using other parameters causes the effect of changes on voltage and frequency is prevented. Therefore by investing in the distribution networks that has not been paid attention for many years, the above goals can be obtained.

*Equipments life, network protectors and equipment depreciation:*

Since the life of equipments depends greatly on their using and operation, by resolving the error the life of equipments may be obtained. In fact, the best solution to solve the problem is to use probability equations and the best distribution is the exponential distribution. (Rahmani, 2004)

Therefore the exponential distribution is used to obtain the lifelong of equipments.

$$F(X) = \lambda e^{-\lambda x}$$

For example the probability of equipment life is 4-6.

$$p(4 < x < 6) = \int_4^6 (\lambda e^{-\lambda x}) dx = \lambda \int_4^6 e^{-\lambda x} dx \Rightarrow \lambda(-\lambda) e^{-\lambda x} = \lambda 2 e^{-\lambda x} \int_4^6 = \lambda^2 [e^{-6} - e^{-4}]$$

*Lack of technical tools adequate for work to identify and restore the fault quickly:*

Today using the remote reclosers, portable detectors and new automatic systems which protect the network against lightning and keep it stable caused to reduce the outage duration.

*B-Non technical factors:*

*Non sensitivity and responsibility:*

The people who feel responsibility for their duties do the following works:

- a – When an outage, outages are occurred they prepare and reinforce the operation team and shorten time of reaching the area as short as it possible.
- b – they prioritize the works to restore the outage quickly.
- c- Always make the required public equipments available in shortest distance and high speed. (Soltani, 2010)

*Sciences and enough experience:*

Using the proper equipment with the correct scientific calculations plays important role to reduce outage. in every circuit breaking the switch and other parts are damaged that if the small fault is not found and informed, it will be leaded to big fault in switch .Every exploiting or working with distribution and power networks requires experiences and information in order to restore the power outage in the shortest time.

*Outage Management:*

*Managing the planned (wanted) outages:*

In feeders or other parts for different reasons especially for repeated faults the outages are occurred with super distribution plan or outages are for repairing and installing the equipments with different natures, therefore

the next plans for outages should be implemented regarding to consumers or customers' tolerance threshold. The planned power outages should be planned base on the work seasons and days. Outages should be imposed when the consumers don't feel requiring power. The planned power interruption or outage should be implemented through maneuver and isolating the fault or defected parts. (Youhannaee, 2012)

*Managing the unplanned (unwanted) power outages:*

Preventive repairs, making the network stable, detecting and identifying the error or fault place correctly, correct decision making, trained personnel's correct actions, explaining the instructions and informing play important role to control the unwanted outages. It is noticeable that using the new tools and technologies of network and employing OMS systems are effective to decrease the outages duration.

*Effective factors to reduce the power outages:*

The effective factors for reducing the outages regard to existing statistics can be explained as below.

*Preventive Maintenance Center (PMC):*

It is a program cycle to do service and repairing the equipments that in addition to cycle of performance the way of doing and required persons to do services and repairs are determined and explained. There is program PMC for network and distribution equipments and the controller or supervision unit control implementing the instructions and works are done in time and correctly.

*Work with warm line:*

The trained personnel for warm line perform service and repairs of network with warm line that every month covers the considerable part of outages.

*Standard networks:*

The standard networks established after Islamic Republic Revolution of Iran and in recent years play important role in stability of network and distribution equipments that the recent assessments confirm this topic.

*Committed and expert human force:*

If the human forces don't use the equipments correctly, not only the equipments can't be exploited and used completely but the effectiveness of equipments will be decreased. Therefore the committed human force with incentive plays important role in effectiveness and efficiency of systems.

*Conclusion:*

It is necessary to reduce as possible the network outages by using the human force's experiences and spending required costs to make the networks stable, doing the service and repairs in time, precise planning, using high quality equipments and exploiting the existed facilities better.

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