# Economic and Environmental Load Flow to Improve Reliability Considering Renewable Energy System

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**Summary**
Nowadays, cases such as restructuring, environmental issues, difficulties and restrictions in the construction of new transmission lines, reducing losses, lack of dependence on fossil fuels, increasing power quality and involving the private sector in production cause the increasing entry of distributed generation systems. Purpose: the purpose of this study is to analyze the sector of the economic and environmental load in order to increase reliability in the presence of renewable resources. Method: the method of this study is descriptive-analytic. In this method, in addition to the imagery of whatever in the research, we also explain and describe the questions and the issues and dimensions in the research. Result: the tendency to use renewable distributed generation systems is increased with the considerable growth of load and the different restrictions of using fossil energy resources. Distributed generation units, according to technology specifications and the location of grid connection, can have positive effects on the power system such as improving the reliability of distribution grids, reducing the loading from feeders and super-distribution posts, and increasing the reliability of the system.

***Keywords***:
*Reliability, renewable resources, hybrid systems, distribution grids, distributed generations*

## 1. Introduction

Distributed generation units can have significant positive effects on distribution grids. Some of the most important cases of these effects, the encourage distribution companies in the installation and setting up of these units are reliability, improving voltage profile, and reducing losses in distribution grids. However, the amount of these effects is dependent upon the number and the situation of the construction of distributed generation units and this fact confirms the need to locate and determine the appropriate capacity of these units. The base and principle of quantitative evaluation of reliability in electric power systems include the definition of basic statements and the topics of useful measurements of reliability and basic data that are required for calculating these indices. Nowadays, with the development of energy generation technologies, the attention to environmental issues, the interest to improve the reliability of electric grids, the required motivation and possibility for changing distribution grids from inactive to mode to active, and the relish for generating renewable energies at the level of the distribution system is increased. In a hand, the connection of distributed generation resources to current distribution grids has not met the technical and economic needs of investors. While it was expected that the quality of electricity would improve with the increase of distributed generation resources penetration coefficient, the results are opposite on account of the power fluctuations derived from voltage and frequency difference of different renewable energy resources. In spite of the fact that the use of distributed generation resources potentially reduce the need for developing traditional electric grids, the control of a large number of them along with controllable loads caused a new challenge to be created in the control and performance of a reliable and economic grid. This challenge somewhat reduces with the reduction in control responsibility of the grid and causes the maximum economic efficiency to be obtained. Thus, the appropriate solution is to build small grids independent from the main grids or micro grids.

Barker et al., (2016) conducted a study analyzing the reliable evaluation of the distribution and super distribution systems with the presence of distributed generation.

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Sagar (2015) conducted a research and evaluated the reliability of power systems including wind power by Monte Carlo method.

## 2. Reliability

Reliability is one of the most important qualitative specifications of items, products, and large and complex systems and has a significant role and importance in the assessment of purpose and the analysis of their current conditions. The whole relations of reliability are based on probabilities. This concept typically used for explaining the degree of reliability of the appropriate function of an item or generally for a collection of factors during a certain period (Arya, 2016).

According to the increase of efficiency importance in energy supply system, competitive conditions in the electricity market and reliable energy supply with high quality for subscribers, more attention has paid to the reliability of supply systems. The combinational renewable energies are the best alternative for supplying electric energy in the areas far from the national grid of electricity or in islands. These resources are dependent upon climate conditions or other factors. In the determination of the hybrid system of wind and sun, observing its randomness is very important (Barabadi et al., 2014).

One of the primary tasks of a power system is to supply electric energy for consumers and this matter must as much as possible be economic and also meet an acceptable level of reliability. As much as the power system's ability in the continuous supply of consumers' power, it considered as reliability while is subject to different events. There are several parameters in power system that impact on the reliability of system (Bertling et al., 2014).

Preventive repair and maintenance are one of the most important actions in distribution grids. One of the ways to reduce unsold energy costs is to do preventive repairs in this area, the existence of a regular and exact plan in this field, and the need for physical analysis of distribution grid and its reliability. Therefore, of the most important strategies to increase the reliability of distribution grids, reduce costs and equipment failure rate is implementing preventing affairs (Briš & Byczanski, 2016).

### 2.1 Measuring reliability

The definition of reliability is based on the definition of failure occurrence. For measuring the reliability of a system, first it is broken down into items and then the reliability of the system is described based on the reliability of its items. A model is selected for failure occurrence rate, in order to calculate the reliability of each item based on the accessible statistical data and its parameters are estimated based on the existing data. Two main functions in the analysis of failure occurrence behavior are failure density functions (f) and hazard rate (z). In a specific period, the failure density is equal to the ratio of the failures in that period to the initial population of the elements, divided by the length of the period. In other words, this indicates the function of mean velocity (or total velocity of failures). But hazard rate can be known as the instantaneous velocity failures which are equal to the ratio of the number of failures in the period to the number of intact elements at the beginning of the period, divided by the period length (Bertling, 2015).

### 2.2 Reliability-based maintenance and repair

It is a systematic process to determine whether or not the whole physical equipment can continuously work in their operational context. The method of reliability-based maintenance and repair is a decision making process for selecting a Net cost-effective plan for improving reliability based on the criticality of failure modes. This method prioritizes the Net requirements of failure modes and selects the effective Net activity for critical failure modes (Dehghanian et al., 2017).

The stages of reliability-based maintenance and repair

- Defining the systems or sub-systems and borders
- Defining the tasks of each system or sub-system and identifying functionally significant item (FSI)
- Identifying the reasons for functionally significant item's failure
- Predicting the effects and the probability of these failures
- Using a decision making tree for identifying the failure effects of FSI

- Identifying effective and applicable net activities and measures that include initial net program
- Redesigning the equipment or process if no applicable activity can be identified
- Forming a dynamic net program which has obtained from the permanent and systematic update of the primary net program and the revision of program through monitoring, collection, and analysis of the servicing system (Abaei Heravi et al., 2016).

## 3. Renewable Resources

Renewable energy resources refer to the resources that are not exhaustible unlike fossil fuels and/or their reproduction or replacement is implemented with a high speed. Some instances of these energies are the wind, solar, sea waves, biomass, geothermal, tide energies etc. On the other hand, researchers propose a place for energy transfer problem. It means that according to this important advantage of renewable energy resources that any types of that can be found on any spot on Earth, the generation of the required energy of any area can be implemented locally and by local resources.

The proper implementation of load response programs and changeable tariffs with time can contribute to the implementation of production and consumption pattern. Flexible loads also considered as ideal complements for renewable energy resources that are typically changeable, fluctuating, and non-permanent. Therefore, the uncertainty of renewable energies can be somewhat compensated through response programs of load and consumption management (Jokar et al., 2015).

The increase of renewable resources penetration has the increase of need for ancillary services such as reserving spinning, frequency regulation, and more slope rate and it practically increases the operation costs. Moreover, in some cases, in the effect of the over-production of renewable units and the shortage of the consumption load, the operator had to mandatorily cut and exit the resources. Therefore, the lack of coordination between production peak and consumption peak is another basic problem of them and this matter results in energy shortage in load peak hours and over-production and over-production in non-peak hours (Despujols, 2015).

### 3.1 Alternative energies

In recent years, the use of renewable energies has had an increasing growth. Different countries, according to their industrial abilities and geographical potentialities are endeavoring to utilize these resources. Enhancing energy safety through reducing the dependency to oil-producing countries is the main reason of industrial countries' attention to renewable energy. The increasing growth of fossil fuels price and the terrible effect of these resources on the environment are other reasons for the motivation of countries to be increased in the use of renewable energy. Several types of research in the field of energy generation through renewable energy resources cause the severe reduction in the price of generative electricity from this method and provide the possibility for competing with non-renewable resources (Fischer et al., 2015).

It should be mentioned that the share of alternative energies in the budget of developed countries is increasing. Until 2010 in the Europe Union, more than 12 percent of the required electricity is produced using alternative energies. Predictions show that despite the fact that renewable energy has many advantages compared to fossil resources, during the next two decades, the growth of the use of fossil energies will be more compared to renewable energies. The less fixed price of electricity energy generation using fossil fuels to the ratio of renewable energies is the most important reason for the justification of this subject. The higher reliability of non-renewable energies can also be referred with the assumption of the accessibility of fossil power plants' fuel against the unpredictability of the time and amount of accessibility to the primary resources of renewable resources. One of the most important purposes of using renewable energy resources is the reduction of costs. The use of renewable energy resources in order to supply the consuming electricity and far from the grid in remote areas is a good solution for reducing the economic costs derived from the extension and transmission of grid lines, reducing environmental pollutions, and increasing the efficiency of energy (Guo et al., 2016).

### 3.2 Solar systems

Solar energy is one of the renewable and clean energies. Photovoltaic equipment directly converts the shone solar radiations to electric energy. Photovoltaic cells form a significant part of photovoltaic power plants. These cells generate electricity like a battery as long as they are exposed to sunlight. A unit named module obtains with the series and parallel connection of cells. With installing a number of solar modules on a preservative page, a larger unit named solar array obtains. The obtained electric power from solar array always has fluctuations owing to the change in environmental conditions in terms of temperature and light intensity. For this reason, a regulator is also needed for gaining the maximum required power. In general, it can be said that a photovoltaic electricity generator unit has formed by solar array fragments, maximum power regulator, energy storage unit, and voltage inverter. This technology is used in the areas where electrification is hard or expensive (in lower capacities) and it has prepared so that they use it at night or when necessary with the reservation of the electric energy generated by sunlight at day (Roozan et al., 2014).

### 3.3 Wind turbines

Wind energy is one of the most frequent renewable resources which its usage is not a new component and it has used many years before the discovery of electricity for circulating windmills. Nowadays, according to the lack of environmental pollution of this type of energy, it is used for generating electricity. In this method, the wind circulates the turbine blades like windmills and it also makes shaft generator to circulate (Hernando et al., 2013).

### 3.4 Hybrid System

A group of electricity generation systems that are fed by different energy sources and work together in the form of hybrid and supplement is known as a hybrid system. Since these systems fed by two or more different energy sources, they have a higher reliability compared to the systems that have one source for generating electricity. Sun and the wind are the most common types of energy sources and hybrid systems that consisted of solar arrays and wind turbines can broadly and appropriately provide the needs of the grid. In one hand, on account of the lack of the certainty of solar radiation and wind speed, their generative energy is unpredictable. Therefore, the capacity of these power plants and their storage systems must be, in order to increase the reliability and the continuous supply of a load, considered much more than the amount of load demand. In hybrid systems, with the combination of two or more sources, the predictability of generation increases and these resources, in fact, somewhat cover their shortages. The generative electricity energy through renewable energy can directly be injected to grid or energy be generated stand-alone from the grid (Low et al., 2016).

### 3.4 Types of hybrid systems

The energy generator hybrid systems are used in two different forms including grid-connected and grid-independent. Each form used and designed considering specific purposes. In hybrid systems independent from the grid, the purpose is to provide a load of the system with the desirable capability. These types of systems are used for providing the remote loads from the grid and on account of the lack of efficiency of transmission heavy costs. In these systems, there is no way for energy to exchange with the grid (Separi & Asadi Kiapi, 2016).

The purpose for the designing the hybrid systems connected to the grid is to supply the demand of load and exchanging power with the grid. When renewable resources are unable to supply the load demand, the power shortage is compensated by the grid. Moreover, the hybrid system can also improve the grid reliability with the injection of power to the grid. In addition, this system can, except the supply of its load, be sold to the electricity grid (Alizadeh & Dashti, 2015).

### 3.5 Hybrid systems reliability assessment

The most important purpose of using hybrid system is to increase the reliability of energy generation. The concept of reliability increase is that the hybrid system be adequately able to supply the required energy for load and the subject of adequacy appears. Adequacy means the system has the ability to adequately supply the load. In one hand, the possibility of losing a load or lack of supply of load energy is at the lowest level. In addition, the hybrid system can supply the load continuously and without interruption, with a desirable reliability, and here the subject of durability appears. Different definitions are

presented for reliability, but the definition that has broadly accepted is as follow: reliability includes the probability that equipment does its job, under utilization conditions and a certain time, correctly (McKenna & Oliverson, 2015).

The implementation of reliability assessments must be considered beside the economic assessments of energy generation by the hybrid system. Therefore, the assessment of economic income derived from the utilization of renewable resources in hybrid systems required the analysis of the reliability level of the system. So this is more needed for reliability subjects to be studied in hybrid systems, on account of the uncertainty of the generation potential of these type of resources (HAMADACHE, 2016).

### 3.6 The economy energy generation from renewable energies

Energy generation from renewable energy resources has the problem of lack of accessibility energy resources (like wind and sun) and the problem of disability of electricity storage in large scale which causes the issues such as lack of dispatch, reducing the utilization capacity of these resources, and reducing the stability of energy supply (Moubray, 2013).

Some ways of developing renewable energies are removing the subsidies of fossil fuels in the direction of eliminating fake prices, the guaranteed purchase of the generated energies, forming tax exemptions, allocating subsidies to this sector especially research and development subsidies, and taxation on pollutants. Moreover, the process of development speeds up with restructuring and de-monopolizing from electricity industry on account of the development of privatization. In addition, regarding the expensiveness feature of renewable energy technologies makes the role of the financial sector and credit markets in the financial support of electricity generation projects more dominant (Piasson et al., 2016).

Generating electricity from renewable energies is an expensive process, and except the costs of the installation of required support capacity for these types of energies, the costs that energy generation is subjected from renewable energies are mostly the costs of capacity installation and fixed operational costs. It includes almost 50 or 80 percent of the whole energy supply costs and this is the main reason for the price level of these resources' generative electricity to be higher than fossil resources. But, a part of these costs can be covered with applying environmental benefits and the fewer costs that these types of energies incur to the community and also the savings derived from the reduction of the costs of fossil fuels (Mohammadi et al., 2016).

### 3.7 Renewable energy resources advantages

- Renewable energy resources have a long durability and natural cycles, unlike nonrenewable energies (fossil fuels) that are coming to an end.
- Renewable energies such as the wind and sunlight energy have a high capability of generating electricity, on account of having free cost and suitable geographical conditions.
- Using renewable energy resources, generation can be easily done at any spot and area proportional to geographical conditions (Vaezizadeh & Moeini, 1394).

The most important sources of distributed generation, based on renewable energies, are solar arrays and wind turbines. These sources have had an increasing development in recent years. Solar arrays and wind turbines convert sun radiant energy and wind blow speed respectively and their generative energy rate changes according to climate conditions, such as sun radiation measure and wind blow speed so that the generative energy of these sources is unpredictable. Lack of control in the generative ability of solar arrays and wind turbines causes the unavailability of its generation planning for different periods. This issue is one of the barriers to the commercial development of this technology and necessitates the urgency of using storage systems (Picknell et al, 2016).

## 4. Distributed generation

Owing to the enhancement of exploitation return and the encouragement of the investors, the electricity industry has been undergone major changes in terms of management and ownership so that its different sections such as generation, transfer, and distribution are separated for forming a suitable competitive space. These

changes in one hand, and factors such as environmental pollution, problems of constructing new transmission lines and other explained problems and also technology advancement in the field of economizing the construction of generation units in small scale on the other hand, cause the formation of tendencies for increasing the use of the small units of power and the generation of local power at the level of distribution voltage by renewable energy sources such as wind power, solar photovoltaic cells, fuel cells, micro turbines, and also a combination of these in distribution grids (Smith et al., 2016).

The advantages and disadvantages of using distributed generation

Distributed generation sources can be used for the simultaneous generation of heat and energy. In this usage, the wasted heat is used for industrial, domestic, and commercial consumptions and usages. This matter causes the efficiency of the unit to be increased and the thermal pollution of the environment to be reduced.

- The reduction of environmental pollution and global warming are considered as significant factors for replacing renewable energy resources for fossil fuels. Many of the countries are decided to reduce greenhouse gasses in order to cope with climate changes and reduce the global warming. With the exploitation of renewable distributed generation resources, it can be expected to generate a power with a more efficiency and less environmental undesirable effects.
- Owing to the rapid growth of load, the need for reducing generative power causes the gradual reduction of the resources of fossil fuels. Therefore, most of the countries consider renewable energy resources as a solution.
- Peak clipping at peak hours
- Releasing the capacity of transmission and distribution systems including lines and posts (Yssaad et al., 2014).

The separate utilization of distributed generation resources can, as much as it causes multiple advantages, cause specific problems in distributed grids and/or power systems. A more appropriate solution for using the high potentialities of these power sources is using a systematic vision about them. It means that these power sources and their corresponding loads must be viewed as a subsystem or micro grid (Zhang et al., 2015).

The stimulant factors of increasing tendency to use distributed generation networks

- Significant industrial advancements in building and using relevant technologies.
- The existing barriers in constructing power transmission lines.
- The inclusion of the subject of the electricity market and related issues in power system.
- The increase of subscribers' requests for a high reliability service
- High sensitivity about environmental pollutions

Distributed generation units can, according to specifications, maintenance conditions, and installation location, have significantly positive effects on distribution grids. One of the most important effects that stimulate distribution companies in set up and installation the most is the improvement system reliability. However, this improvement is dependent on the specifications, number, and the construction situation of distributed generation units. In fact, this matter contributes to the necessity of the appropriate placement and capacitation of these units (Arya, 2016).

## 5. Micro grids

The penetration of distributed generations in distribution grids results in the issues that suspect the more development and penetration of distributed generations in distribution grids from the view of grid designer. With the more advancement of the technology and engineering of power systems, grid designers are able to cope with the most of these issues and more benefit the distribution grids from the advantage of distributed generation. Therefore, little by little, the distribution grids are formed that are able to generate and also control their grids, similar to large power grids. Micro grid refers to a group of loads and small sources of power that can operate as a controllable system and

simultaneously generate electric power and heat (Barabadi et al., 2014). The differences between the power sources of a micro grid and the powers grids of conventional electric grids

- In some economic reasons, a significant section of micro grid power is provided through uncontrollable sources like wind. While in traditional systems, only a section of the power of these resources is provided, in the case of the loss of these resources, the power balance quickly forms water or steam power plants.
- The capacity of micro grid power sources is much less than the large generators of conventional grids plants.
- Energy storage units, long term or short term, play a significant role in controlling the performance of micro grid. While in traditional systems, storage units have not such a significant role.
- Generative power, at the level of distribution voltage, can be directly connected to the distribution grid.
- Micro grid power resources are usually installed near the consumers in order for thermal and electric loads to be fed with a higher efficiency and a more suitable voltage profile and also fewer losses (Briš & Byczanski, 2016).

The reasons for the appearance of micro grids Despite distributed generations owing to the increase in the number of power generation in the grid, the task of control and exploitation from the whole grid is almost impossible with the centralized mode. In fact, micro grid implements the decentralized control of this active grid. It means every micro grid exploit and control its grid in the best possible way. One of the most important purposes, in order to step toward micro grid, is preventing energy losses. In micro grid, with the presence of distributed generation resources near the consumers, both the generated electric energy and the thermal energy derived from the generator resources can be used (Fischer et al., 2015).

The use of micro grids increases the reliability of the system. According to the fact that micro grid can supply the consumption power of its subscribers at the time of the error and with the island mode, then reliability in these grids is way more compared to the normal grids. Some of the reasons for micro grids to emerge are as follow: the better control of distributed generation sources for better feeding the grid load; low impact on electric grids with the adaption of load and production in micro grid; reducing the negative effects of the presence of generation resources on the grid; the better use of fuel sources or in other words the increase of the efficiency of using fossil energy; differentiating among various loads (sensitive or insensitive) (Bertling et al., 2014).

## 6. Distribution grids

Electric energy distribution grids are the broadest section of the power system. These grids are the mediators between the consumer and transmission and generation system and they have a specific sensitivity on account of proximity with the consumer. One of the ways of improving the reliability of distribution grids is installing intelligent equipment in order to rearrange the defected feeder and reduce the off time. Owing to the radial structure and also the diversity of the used equipment, the distribution grids assigned the highest share in the unreliability of the system to themselves. Hence, the statistics and analyses indicate that almost 90% of subscribers' turn offs are related to the distribution system (Dehghanian et al., 2017).

After the occurrence of an error in a radial distribution grid, even in case of the optimal location of all the mentioned equipment, if other system equipment such as transformers and conductors do not have the required capacity for supplying the added load to them during retrieving the service of off areas, the load of these areas must still be off. This matter causes the reduction of reliability of the distribution system and causes the increase of its related damages such as damages to the consumer. In the case of any error on a distribution feeder, the first step is to identify the place of the error and it takes time due to the situation of the place (distance from the seating of the group of events). The separation of the error location and the grid maneuver is implemented through an opening or closing a number of sectionner in order for damaged areas from the other areas of the feeder be separated and the remained areas through the adjacent feeders to be electrically supplied (Guo et al., 2016).

5.1 assessing the reliability of distribution grids

Multiple methods are represented for assessing the reliability of distribution grids and all of them are almost based on two main methods: analysis and simulation methods.

In analytic methods that are commonly used in the engineering studies of the reliability of distribution systems, the related equipment in the form of math are modeled as series or parallel components and the related indices are calculated in a relatively short time. The most important analytic methods include Markov method, error mode and the analysis of its effect, the minimum cut-set method, and analysis method of events tree (Ebaei Heravi et al., 2016).

About the simulation-based methods, various methods have been proposed for the reliability evaluation and they are more or less related to Monte Carlo simulation. In Monte Carlo method, the reliability is implemented using the consecutive simulation of a real action with the random behavior in the system. In this method, due to the random nature of the issue, the number of errors, the time between errors, duration of retrieval of the load etc. can have any level or number. Evaluation based on these methods needs to spend a lot of time (Bestani Omleshi, 2016).

Distribution posts and weak voltage grid Distribution posts reduce the voltage from the medium voltage grid to consumption voltage. These posts are used in two forms, according to the high difference in load density and the existence of restrictions in different areas:

a. Ground posts: it used in urban areas with high load density of large transformers and these posts feed the consumers through ground cables.
a. Air posts: this type of posts is mostly used in rural or urban areas with light load density and fed by Air medium voltage feeders (Separi & Asadi Kiapi, 2016).

Low-voltage circuits, followed by consumer service connections, form the last part of the distribution grids and they directly communicate with consumers. These feeders are basically equal with medium voltage feeders, in terms of the circumstance of servicing. Practically, low voltage grids and distribution transformers are placed in an area where there is a close relationship between them. In calculating the reliability evaluation of medium voltage distribution grids, the Distribution transformer and the low voltage grid connected to it (in other words, the downstream grid of distribution posts) are considered as a load point for medium voltage grid. Therefore, in MV distribution system reliability analyses, a distribution transformer along with its downstream grid is modeled as a load point and reliability indices related to this spot are defined and calculated (Low et al., 2016).

## 7. Conclusion

One of the measures to increase the reliability in the design and exploitation of distribution grids is reducing the system's recycle time after an error. The results of Researches confirms that the use of distributed generation units in distribution grids can have a significant impact on reducing the continuity duration of blackouts for load points and improving the reliability of distribution grids. Also, the improvement level in the level of system reliability which achieved due to the installation of distributed generation is dependent upon Installation location, capacity, and a number of units. Distributed generation units play a more significant role in reducing system reliability indices than the old units.

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