International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

DISTRIBUTED GENERATION SYSTEM ANALYSIS WITH ADAPTIVE VOLTAGE CONTROL DESIGN: REVIEW

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ABSTRACT

This thesis present a robust adaptive voltage control of three-phase voltage source inverter for a distributed generation system using harmonic filter. Proposed adaptive voltage control technique combines an adaption control term, harmonic filter and a state feedback control term. In addition, the proposed algorithm is depend upon the existing work, so we are incorporating the harmonic filter , by using of these filter we can analyze and measure the voltage changes accordingly existing research . In this paper, also we can see the graph for the active ad reactive power for the three phase inverter source. The simulation and experimental results are presented under the parameter uncertainties and are compared to the performances of the corresponding adaptive voltage controller to proposed control schematic filter using harm.

1. INTRODUCTION

In recent years, eco-friendly distributed generation systems (DGS) such as wind turbines, solar cells, and fuel cells are dramatically growing because they can fulfill the increasing demand of electric power due to the rapid growth of theeconomy and strict environmental regulations regarding greenhouse gas emissions [1]–[8].

Generally, the DGSs are interconnected in parallel with the electric utility grid and provide maximum electric power to the grid. However, there aresome areas (e.g., remote islands or villages) where the connection to the gridis expensive or impractical and then small scaled standalone DGSs are the only efficient and economical options.

In such DGSs, depending on consumers' power demand, there are situations where some DGSs operate in parallel [9]–[11] or independently [12]– [14]. In either case, a stable operation of each DGS unit is as important as the stability of the parallel operating DGSs inwhich the proper load sharing of eachunit is one of main research issues since the voltage controller is commonly used ina single DGS unit or multiple DGS units.

For this reason, the voltage controller design for a single DGS unit, which can guarantee a good voltage regulation under unbalanced and nonlinear loads, is an interesting topic in the field of the DGSs control. For the purpose of improving the quality of inverter output voltage, many researchers are working on designing the controllers for dc–ac power converters.

In [15], a control scheme based on the transfer function of the nominal plant is proposed for an electronically coupled DG unit in an islanded mode. This control method is suitable for a prespecified and balanced load condition, but cannot cover the large load variations. In [16], a robust controller is developed for balanced and unbalanced systems, which considers the uncertainties of the load parameters. However, nonlinear load is not fully addressed.

In [17], a repetitive control is used to regulate the UPS inverters. However, the slow response and lack of the systematic method to stabilize the error dynamics with the repetitive control are being the main problems. In [18], an alternative control strategy with a feed forward compensation component can significantly mitigate the effect of load disturbance and make the controller design simple. Nevertheless, the application of this method is mainly limited to balanced load conditions.

In [19], a current control technique based on the spatial repetitive control is applied to a single-phase inverter and it also improves the performance of the current controller by estimating the disturbances. Although this control can obtain good results under nonlinear load, it may not guarantee agood voltage tracking capacity for a three-phase system.

In [20], a robust servomechanism voltage controller and a discrete-time sliding mode current controller are presented to control a single distributed generation unit in a standalone mode which can operate well under a sudden load change, an unbalanced load, and a nonlinear load. However, the controller provided in [20] is quite complicated.

In [21], a voltage and frequency control strategy based on a discrete-time mathematical model is proposed for the islanded operation of dispatch able electronically coupled distributed- resource units. The method [21] can achieve good voltage regulation under various load types. However, no experimental results are shown to verify the usefulness of the proposed method.

An adaptive feed forward compensation controller is presented in[22] for micro-grid applications. Because a Kalman filter is applied for online estimating the system parameters, this control scheme is robust to parameter variations. However, the tuning of covariance matrices, which is one of difficult tasks, is not stated in the paper.

In [23], a complementary controller is suggested for DGS units in grid-connected applications. Although this controller can deal with nonlinearities and grid disturbances, the design of the current control loop seems to be complicated. In addition, this control scheme is not applicable in an islanded mode because it is lack of voltage control loop.

Recently, an adaptive control method has been widely considered in the standalone DGS or UPS voltage control. In

[24] and [25], the precise voltage tracking is achieved under distorting loads by using the adaptive control for the output voltage based on the ideas of dissipativity. In these papers, the uncertainties in the system parameters are addressed through the adaptation, and the stability of the system is guaranteed even under system parameters variations.

However, the major drawback of these techniques is the computation complexity. In order to reduce this complexity, a certain predefined value for the parameters is required. In [26], an adaptive output voltage controller based on the resonant harmonic filters, which measures the capacitor current and the load currents in the same sensor, is proposed in order to compensate for the unbalance and harmonic distortion on the load.

The adaptation law is also included to cope with the uncertainties in the system parameters. However, the information about output voltage THD is not presented so it is not easy to evaluate the quality of the controllers. In [27], an adaptive control method based on the proportional-derivative control technique is presented for a pulse width modulation (PWM) inverter operation in an islanded DGS.

This paper can guarantee goodvoltage regulation under various operating conditions such as sudden load changes, unbalanced load, and nonlinear load. However, it is not an easy task to choose the appropriate control gains according tothe design procedure mentioned in the paper.

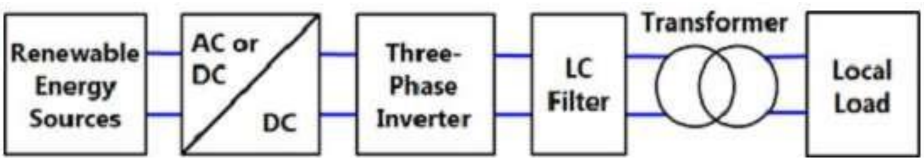

Fig. 1.1 Block diagram of a standalone DGS using renewable energy sources.

After considering the disadvantages of the above published papers, this paper proposes a robust adaptive voltage controller of the three-phase voltage source inverter for a standalone DGS with various types of loads. First, the state- space model of the three-phase inverter is derived, which considers the uncertainties of system parameters. The proposed adaptive control technique combines an adaption control part and a state feedback control part.

The adaption control part compensates for system uncertainties, whereas the state feedback control part forces the error dynamics to converge exponentially to zero. The proposed control strategy is not only simple, but also insensitive to system uncertainties and sudden load disturbances. It should be noted that almost all published papers [15]–[20], [27] do not study the effects of the uncertainties in the system parameters.

Moreover, it is proven that the proposed closed-loop control system is globally stable. The proposed adaptive controller ensures outstanding voltage control performance (i.e., fast transient response, small steady-state error, and low THD) under various types of loads (i.e., balanced load, unbalanced load, and nonlinear load).

These features can overcome the drawbacks (e.g., no results/high THD under nonlinear and unbalanced loads) of previously published papers [15]–[19], [27]. To confirm the feasibility of the proposed control algorithm, simulations and experiments are performed through Matlab/Simulink software and a prototype DGS test-bed with a TMS320F28335DSP and are compared to the performances of the corresponding non-adaptive voltage controller.

2. DISTRIBUTED GENERATION

Distributed generation, also called on-site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy or distributed energy generates electricity from many small energy sources. Currently, industrial countries generate most of their electricity in large centralized facilities, such as fossil fuel (coal, gas powered) nuclear or hydropower plants.

These plants have excellent economies of scale, but usually transmit electricity long distances and negatively affect the environment. Most plants are built this way due to a number of economic, health & safety, logistical, environmental, geographical and geological factors. For example, coal power plants are built away from cities to prevent their heavy air pollution from affecting the populace.

In addition, such plants are often built near collieries to minimize the cost of transporting coal. Hydroelectric plants are by their nature limited to operating at sites with sufficient water flow. Most power plants are often considered to be too far away for their waste heat to be used for heating buildings.

Low pollution is a crucial advantage of combined cycle plants that burn natural gas. The low pollution permits the plants to be near enough to a city to be used for district heating and cooling. Distributed generation is another approach. It reduces the amount of energy lost in transmitting electricity because the electricity is generated very near where it is used, perhaps even in the same building.

This also reduces the size and number of power lines that must be constructed. Typical distributed power sources in a Feed-in Tariff (FIT) scheme have low maintenance, low pollution and high efficiencies. In the past, these traits required dedicated operating engineers and large complex plants to reduce pollution. However, modern embedded systems can provide these traits with automated operation and renewables, such as sunlight, wind and geothermal. This reduces the size of power plant that can show a profit.

3. DISTRIBUTED ENERGY RESOURCE

Distributed energy resource (DER) systems are small-scale power generation technologies (typically in the range of 3 kW to 10,000 kW) used to provide an alternative to or an enhancement of the traditional electric power system. The usual problems with distributed generators are their high costs. One popular source is solar panels on the roofs of buildings.

The production cost is $0.99 to 2.00/W (2007) plus installation and supporting equipment unless the installation is Do it yourself (DIY) bringing the cost to $6.50 to 7.50 (2007).[1] This is comparable to coal power plant costs of $0.582 to 0.906/W (1979),[2][3] adjusting for inflation. Nuclear power is higher at $2.2 to $6.00/W (2007).[4]

Some solar cells ("thin-film" type) also have waste disposal issues, since "thin-film" type solar cells often heavy-metal electronic wastes, such as Cadmium telluride (CdTe) and Copper indium gallium selenide (CuInGaSe), and need to be recycled. As opposed to silicon semi-conductor type solar cells which is made from quartz.

The plus side is that unlike coal and nuclear, there are no fuel costs, pollution, mining safety or operating safety issues. Solar also has a low duty cycle, producing peak power at local noon each day. Average duty cycle is typically 20%. Another source is small wind turbines. These have low maintenance, and low pollution.

Construction costs are higher ($0.80/W, 2007) per watt than large power plants, except in very windy areas. Wind towers and generators havesubstantial insurable liabilities caused by high winds, but good operating safety. In some areas of the US there may also be Property Tax costs involved with wind turbines that are not offset by incentives or accelerated depreciation.

Wind also tends to be complementary to solar; on days there is no sun there tends to be wind and vice versa.[citation needed] Many distributed generation sites combine wind power and solar power such as Slippery Rock University, which can be monitored online. Distributed cogeneration sources use natural gas-fired microturbines or reciprocating engines to turn generators.

The hot exhaust is then used for space or water heating, or to drive an absorptive chiller [6] for air- conditioning. The clean fuel has only low pollution. Designs currently have uneven reliability, with some makes having excellent maintenance costs, and others being unacceptable. Co-generators are also more expensive per watt than central generators. They find favor because most buildings already burn fuels, and the cogeneration can extract more value from the fuel.

Some larger installations utilize combined cycle generation. Usually this consists of a gas turbine whose exhaust boils water for a steam turbine in a Rankine cycle. The condenser of the steam cycle provides the heat for space heating or an absorptive chiller. Combined cycle plants with cogeneration have the highest known thermal efficiencies, often exceeding 85%.

In countries with high pressure gas distribution, small turbines can be used to bring the gas pressure to domestic levels whilst extracting useful energy. If the UK were to implement this countrywide an additional 2-4 GWe would become available. (Note that the energy is already being generated elsewhere to provide the high initial gas pressure - this method simply distributes the energy via a different route.)

Future generations of electric vehicles will have the ability to deliver power from the battery into the grid when needed. This could also be an important distributed generation resource. Recently interest in Distributed Energy Systems (DES) is increasing, particularly onsite generation.

This interest is because larger power plants are economically unfeasible in many regions due to increasing system and fuel costs, and more strict environmental regulations. In addition, recent technological advances in small generators, Power Electronics, and energy storage devices have provided a new opportunity for distributed energy resources at the distribution level, and especially, the incentive laws to utilize renewable energies has also encouraged a more decentralized approach to power delivery.

There are many generation sources for DES: conventional technologies (diesel or natural gas engines), emerging technologies (micro turbines or fuel cells or energy storage devices), and renewable technologies (small wind turbines or solar/photovoltaic's or small hydro turbines).

These DES are used for applications to a standalone, a standby, a grid-interconnected, a cogeneration, peak shavings, etc. and have many advantages such as environmental-friendly and modular electric generation, increased reliability, high power quality, uninterruptible service, cost savings, on-site generation, expandability, etc.

So many utility companies are trying to construct small distribution stations combined with several DES available at the regions, instead of large Power plants. Basically, these technologies are based on notably advanced Power Electronics because all DES require Power Converters, interconnection techniques, and electronic control units.

That is, all power genera ed by DES is generated as DC Power, and then all the power fed to the DC distribution bus is again converted into an AC power with fixed magnitude and frequency by control units using Digital Signal Processor (DSP). So improved power electronic technologies that permit grid interconnection of asynchronous generation sources are definitely required to support distributed generation resources.

The research works in the recent papers about DES focus on being utilized directly to a standalone AC system or fed back to the utility mains. That is, when in normal operation or main failures, DES directly supply loads with power (standalone mode or standby mode), while, when DES have surplus power or need more power, this system operates in parallel mode to the mains.

Therefore, in order to permit to connect more generators on the network in good conditions, a good technique about interconnection with the grid and voltage regulations should overcome the problems due to parallel operation of Power Converter for applications to DES.

4. DISTRIBUTED ENERGY SYSTEMS

Today, new advances in technology and new directions in electricity regulation encourage a significant increase of distributed generation resources around the world. As shown in Fig. the currently competitive small generation units and the incentive laws to use renewable energies force electric utility companies to construct an increasing number of distributed generation units on its distribution network, instead of large central power plants.

Moreover, DES can offer improved service reliability, better economics and a reduced dependence on the local utility. Distributed Generation Systems have mainly been used as a standby power source for critical businesses. For example, most hospitals and office buildings had stand-by diesel generation as an emergency power source for use only during outages.

However, the diesel generators were not inherently cost-effective, and produce noise and exhaust that would be objectionable on anything except for an emergency basis.

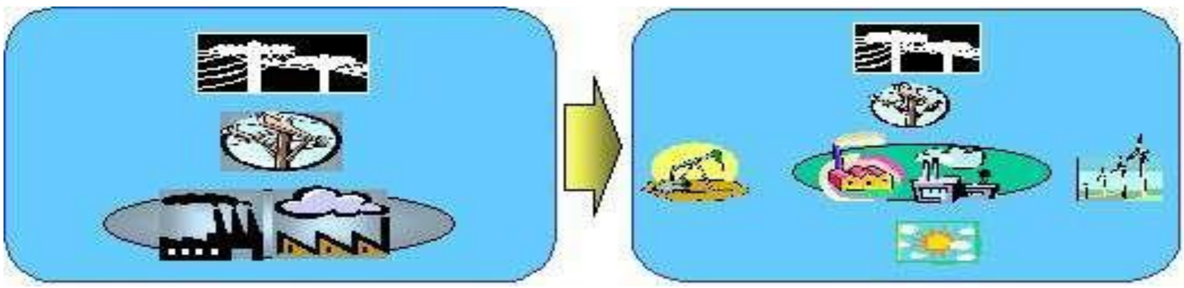

Fig. 2.1 Large central power plant and distributed energy systems

Meanwhile, recently, the use of Distributed Energy Systems under the 500 kW level is rapidly increasing due to recent technology improvements in small generators, power electronics, and energy storage devices.

Efficient clean fossil fuels technologies such as micro-turbines and fuel cells, and environmentally friendly renewable energy technologies such as solar/photovoltaics, small wind and hydro are increasingly used for new distributed generation systems.

These DES are applied to a standalone, a standby, a grid- interconnected, a cogeneration, peak shavings, etc. and have a lot of benefits such as environmental-friendly and modular electric generation, increased reliability, high power quality, uninterruptible service, cost savings, on-site generation, expandability, etc.

The major Distributed Generation technologies that will be discussed in this section are as follows: micro-turbines, fuel cells, solar/photovoltaic systems, and energy storage devices. Micro-turbines,

especially the small gas fired micro turbines in the 25-100 kW that can be mass-produced at low cost have been more attractive due to the competitive price of natural gas, low installation and maintenance costs.

It takes very clever engineering and use of innovative design (e.g. air bearing, recuperation) to achieve reasonable efficiency and costs in machines of lower output, and a big advantage of these systems is small because these mainly use high-speed turbines (50,000-90,000 RPM) with air foil bearings. Therefore, micro turbines hold the most promise of any of the DES technologies today.

Fuel cells are also well used for distributed generation applications, and can essentially be described as batteries which never become discharged as long as hydrogen and oxygen are continuously provided. The hydrogen can be supplied directly, or produced from natural gas, or liquid fuels such as alcohols, or gasoline. Each unit ranges in size from 3 – 250 kW or larger MW size.

Even if they offer high efficiency and low emissions, today's costs are high. Phosphoric acid cell are commercially available in the range of the 200 kW, while solid oxide and molten carbonate cell are in a pre-commercial stage of development. The possibility of using gasoline as a fuel for cells has resulted in a major development effort by the automotive companies.

The recent research work about fuel cells is focused towards the polymer electrolyte membrane (PEM) fuel cells. Fuel cells in sizes greater than 200 kW, hold promise beyond 2005, but residential size fuel cells are unlikely to have any significant market impact any time soon. Mixed micro-turbine and fuel cell systems will also be available as a distributed generation source.

Recently, a solid oxide fuel cell has been combined with a gas micro-turbine creating a combined cycle power plant. It has expected electrical efficiency of greater than 70 %, and the expected power levels range from 250 kW to 2.5 MW. Solar/photovoltaic systems may be used in a variety of sizes, but the installation of large numbers of photovoltaic systems is undesirable due

to high land costs and in many geographic areas with poor intensity and reliability of sunlight.

In general, almost one acre of land would be needed to provide 150 kW of electricity, so solar/photovoltaic systems will continue to have limited applications in the future. Energy storage devices such as ultra capacitors, batteries, and flywheels are one of the most critical technologies for DES. In general, the electrochemical capacitor has high power density as well as good energy density.

In particular, ultra capacitors have several benefits such as high pulse power capacity, long lifetime, high power density, low ESR, and very thin and tight. In contrast, batteries have higher energy density, but lower power density and short lifetime relative to ultra-capacitor. So hybrid Power System, a combination of ultra-capacitor and battery, is strongly recommended to satisfy several requirements and to optimize system performance.

Recently storage systems are much more efficient, cheaper, and longer than five years ago. In particular, flywheel systems can generate 700 kW for 5 seconds, while 28-cell ultra capacitorscan provide up to 12.5 kW for a few seconds. In the past, the electric utility industry did not offer various options that were suited for a wide range of consumer needs, and most utilities offered at best two or three combinations of reliability- price.

However, the types of modern DES give commercial electric consumers various options in a wider range of reliability-price combinations. For these reasons, DES will be very likely to thrive in the next 20 years, and especially, distributed generation technologies will have a much greater market potential in areas with high electricity costs and low reliability such as in developing countries.

5. PROBLEM STATEMENTS

DES technologies have very different issues compared with traditional centralized power sources. For example, they are applied to the mains or the loads with voltage of 480 volts or less; and require power converters and different strategies of control and dispatch. All of these energy technologies provide a DC

output which requires power electronic interfaces with the distribution power networks and its loads.

In most cases the conversion isperformed by using a voltage sourceinverter (VSI) with a possibility of pulse width modulation (PWM) that provides fast regulation for voltage magnitude. Power electronic interfaces introduce new control issues, but at the same time, new possibilities. For example, a system which consists of micro-generators and storage devices could be designed to operate in both an autonomous mode and connected to the power grid.

One large class of problems isrelated to the fact that the power sources such as micro-turbines and fuel cell have slow response and their inertia is much less. It must be remembered that the current power systems have storage in generators' inertia, and this may result in a slight reduction in system frequency. As these generators become more compact, the need to link them to lower network voltage is significantly increasing.

However, without any medium voltage networks adaptation, this fastexpansion can affect the quality of supply as well as the public and equipment safety because distribution networks have not been designed to connect a significant amount of generation. Therefore, a new voltage control system to facilitate the connection of distributed generation resources to distribution networks should be developed.

In many cases there are also major technical barriers to operating independently in a standalone AC system, or to connecting small generation systems to the electrical distribution network with lower voltage, and the recent research issues includes:-

1. Control strategy to facilitate the connection of distributed generation resources to distribution networks using the harmonic filter.

2. Inverter control based on only local information.

3. Synchronization with the utility mains.

4. Compensation of the reactive power and higher harmonic components.

5. Power Factor Correction.

6. System protection.

7. Reliability of communication.

8. Requirements of the customer.

9. Active and reactive power measurement

Hence, future research work will focus on solving the above issues so that DES with more advantages compared with tradition large power plants can thrive in electric power industry.

6. PROBLEM DESCRIPTION

These new distributed generations interconnected to the low grid voltage or low load voltage cause new problems which require innovative approaches to managing and operating the distributed resources.

In the fields of Power Electronics, the recent papers have focused on applications of a standby generation, a standalone AC system, a combined heat and power (cogeneration) system, and interconnection with the grid of distribution generations on the distribution network, and have suggested technical solutions which would permit to connect more generators on the network in good conditions and to perform a good voltage regulation.

Depending on the load, generation level, and local connection conditions, each generator can cause the problems described in the previous chapter. The main goals which should be achieved will thus be: to increase the network connection capacity by allowing more consumers and producer customers connection without creating new reinforcement costs, to enhance the reliability of the systems by the protections, to improve the overall quality of supply with a best voltage control.

7. CONCLUSION

We represent a robust adaptive voltage control strategy with harmonic filter of a three-phase inverter for a standalone distributed generation unit with changes in active and reactive power generation. This method is not only simple, but is also robust to system uncertainties with the used of harmonic filter.

Finally, the simulation and experimental results have demonstrated that the proposed control scheme gives satisfactory voltage regulation performance such as fast dynamic behavior, small steady-state error, and low THD under various loads (i.e., no load, balanced load, unbalanced load, and nonlinear load) in the presence of the uncertainties of system parameters.

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