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Voltage Based Control of DG Units in Smart Micro Grids

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Abstract: The micro grids focus on the islanded mode of the micro grid with the control strategies for both the DG units and the active loads. The Dg unit's uses voltage-based droop controllers for power balancing and sharing b/w multiple units. These controllers provide the primary control in the islanded micro grid without communications, which increase the reliability of the system The droop controller is based n the mainly resistive line parameters of the low voltage micro grid and lack of rotating inertia. The paper focuses on the islanded operation of the micro grid, with the control strategies for both the DG units and active load. The DG unit use voltage-based droop controller for power balancing and sharing between multiple units. The controller provides the primary control in the islanded micro grid without communication which increase the reliability of the system. An active load control strategy integrated in the micro grid can offer the needed flexibility and change the current load following control to a more generation following strategy, which burdens the DG units less and avoids frequently changing the power of the renewable energy sources from their optimal operating point.

Keywords: Distributed Generation, Smart Micro Grid, PCC (Point of Common Coupling)

1. Introduction

The reason for the smart grid development in the DG units is the ageing of electric power system. It is not to be expected that the smart grid would remain a revolution in the electric power system. The smart micro grid enables a coordinated control of DG units, storage, a active load, optimized more intelligence in the network. The voltage-based droop control of the DG units operates without a communication to ensures a proper voltage control, power sharing and balancing and a stable a reliable operation of the micro grid. The smart grid development is to manage with the Distributed Generation (DG) units The smart grid is expected to emerge from smart micro grids. The microgrids are defined as the cluster (controllable loads), storage and DG units, often consist of renewable sources. They offer a coordinated approach to integrate DG units power electronically connected in the electrical power system [1]. The microgrid operation in both modes as a grid connected and islanded mode by PCC switch. In the islanded operation the power balancing is to be done using the power switch. Therefore the technical challenges is to develop advanced control strategies to live up to the expectation with micro grids.eg micro grids.

1) It can operate with the utility network as a controllable switch, offering scale effects from the micro grids point of view and reduced complexity for the utility point of view.
2) Facilitate the integration of large amount of DG units especially with renewable energy sources.
3) It can increase the reliability of the system.
4) Support the integration of the smart grid concept in a coordinated manner. The DG units uses low voltage-based droop controllers for power balanced should be maintain and sharing between the multiple units. These controllers provided the primary control In the islanded micro grid without communication which increases the reliability of the system. The droop controllers are based on mainly resistive line parameters of the low voltage micro grid and the lack of rotating inertia. The power of the dispatchable DG units is changed more frequently than that of the renewable energy sources which had power changes that are delayed to the

situation where Dispatchable DG units alone cannot guarantee a stable operation. This enables an optimum use of renewable sources without the need for communications. The active load control can be divided into primary and secondary load control. Analogously to the current grid frequency control, the primary active load control focusses on increasing the reliability of the system. The contribution of the voltage-based droop control strategy of both the generators and the active loads allows a reliable power supply without inter unit communication for the primary control. It leads to a more efficient usage of the renewable energy and can lead to a more efficient usage of the renewable energy and can lead to an increase in the share of renewables in the islanded micro grids.

1.1. Control Strategies for the DG Units

A micro grid can manage, energy production, storage and consumptions such that an islanded mode they become self-sufficiently increasing the reliability of a system. In grid connected mode they enable an effective management of the renewable generation, becomes controllable units of the distribution system and other redundancy in the system. To guarantee a stable operation of microgrids in islanded mode, several control strategies for DG units have been developed. The DG units are power interfaced to the electric network controlling of DG units concerns the control of these interfaces namely the converter control.

1.2. Communication Based DG Unit Control

The control schemes can achieve good voltage regulation and power sharing. However, these control strategies require expensive and vulnerable communication lines which are especially restrictive in case of long distances. Although in geographically small micro grids this is less problematic. These communication links could lead in the reduction of flexibility and expansion thus limiting the flexibility of the system. The best known effective and institutive ways in sharing of the power and voltage control in islanded microgrids based communication are central control, distributed control and master/slave control. The central controller method coordinates the power electronics interface in the micro grid to maintain the balance in active power P and Reactive Power Q in steady state conditions [2, 3]. A central controller defines the set value of the current for each module and its responsible for the power distribution. The central control unit measures the total load current IL. The total current iL is divided between N modules in order to define the reference current for each sub-unit iL/N. The local controllers of ach modules control from their output current to the reference current received from the central controllers. The distributed control method is a variant of central control. In the distributed control method, a central controller provides the fundamental frequency sharing between the different converters by distribution of a low bandwidth to all the converters [4, 5]. In the master /slave control strategy, it provides voltage regulation and specifies the reference current for the slaves. [6, 7] The slave's unit operates as current controllers, tracking the current iref provided by the master. Master/slave control can also be combined with central control unit that distribute the load currents to all slave units.

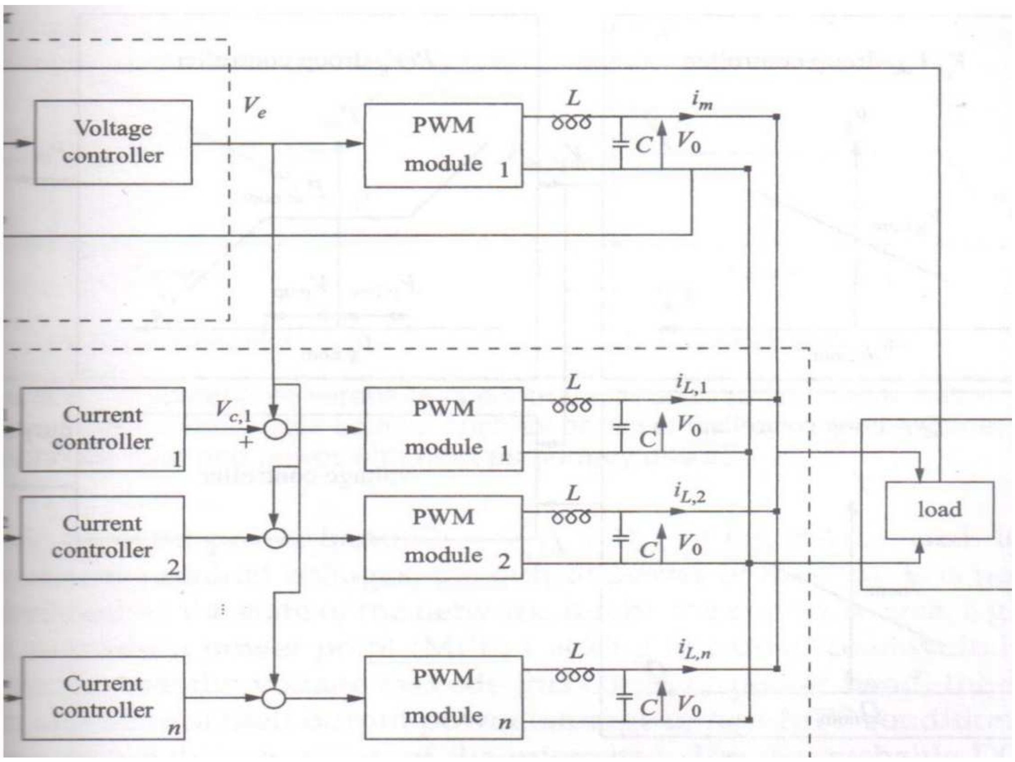

Figure 1. *Schematic overview of master/slave control.*

1.3. DG Unit Controllers Without Communication

To avoid inter -unit communication links that can reduces t the reliability of the system and form a single, point of failure the droop-based control method is widely known. In inductive lines the P/F droops are used, analogous to the conventional grid control [8-11]. However, in resistive micro grid a linkage between the active power and grid voltage instead of phase angle which exist. Therefore P/V droop control also called as reversed droop control [12, 13] Some of variants to improve the droop control strategy are the virtual output impedance method [14, 15] and it usage of the derivative instead of purely proportional controllers in [16-18] order to obtain an optimimum integration of renewable energy sources in the micro grids., the voltage-based droop control for active power sharing between multiple DG units has been developed [19]. As shown in this case the reference voltage amplitude requirement is the active power controller while phase angle is calculated by Q/F droop controller. A voltage-based droop controller consists of cascade of two controllers for the active power sharing. as shown in the given 2 Firstly Vg/Vdc droop control taken care of the power balancing in the network. Analogous to grid frequency in conventional network with rotating inertia, changes of the DC link voltages of the inverters represents the change, the balance in the production and consumption of the network. The control strategy changes the grid voltage Vs proportional to the Dc link voltage of the Vdc of DG unit. Even a slight change of Vg is proportional to the Dc link voltage Vdc of the DG units. Even a slight change of Vg leads to a change of the power delivered electrical network by the inverter. In order to avoid voltage limit violation, the Pdc/Vg droop controller in turn changes the DC power of DG unit dependent on Vg. [20] The power changes by the Pdc/Vg droop controller of the RES are delayed as compared to those of the dispatchable unit. For Figure 2 RES, for example, a wide constant power band (2b=Vglow+Vgup) is used.

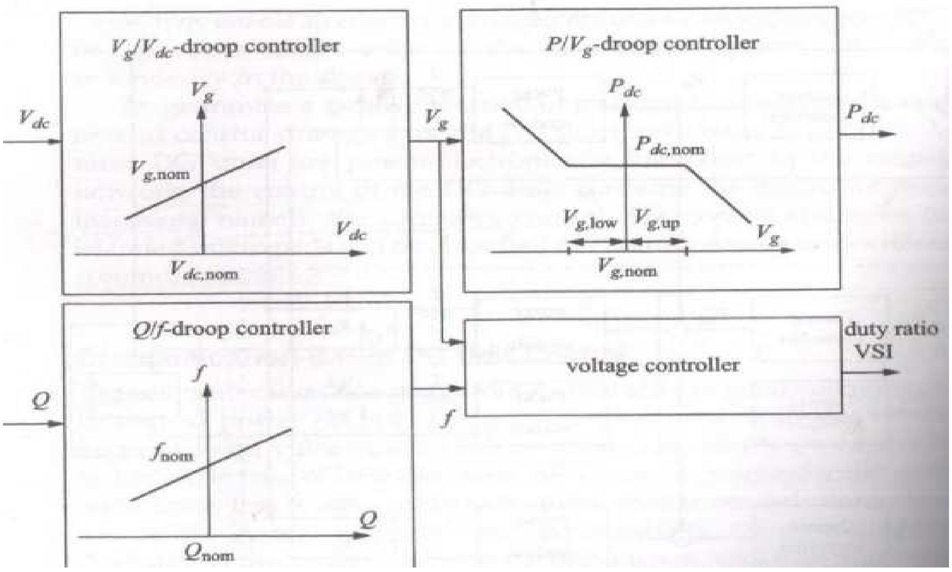

Figure 2. *Voltage Based Droop Control consisting Vg/Vdc and Pdc/Vg droop control. and the consumers perspective.*

The main benefit from the grid point of view is that the micro grid appears to the power network as a single controllable unit enabling it to the consumers point of view the impact of micro grid on the reliability of the distribution network in a relevant certainly in future, with more unpredictable generation and higher consumptions (peaks).

A smart micro grid is a micro grid with intelligent software to monitor, manage, and optimize energy supply, storage and demand which can:

(1) It contains energy management system.
(2) Monitor the system and actively intervene in the consumption /generation.
(3) Identification and maximization of the energy efficiency opportunities.
(4) Use an extra communication and sensors layers to maximize the cost savings and reduces carbon emission.
(5) The generation of major active participation of the consumers. It is expected that the smart grid will emerge as a revolution it will rather experience a gradual revolution with smart grid emerging as a system of integrated smart micro grid. The flexibility and scalability, microgrids have pointed out the main actor in the development of the smart grid. The smart micro grid makes intelligent.

1.4. Control Strategies for the Active Loads

The grid control is currently based on following strategy, whereas the generator follows the load changes without influencing the loads. In the load following strategy, the loads are quasi binds to the state of the network. The advent of large amount of DG units leads to a relative decrease of centralized.

Power plants compared to units with an intermittent variable character, which are often Dg units (e.g. winds, solar). Therefore, control flexibility of the generator to face the variability of the loads decrease in case of the high amount of DG in the network. Both the production and demand become variable and to adjust them such that production exactly matches demand becomes very complex. As the available storage capacity is mostly limited and expensive, a solution often presented is the usage of active load control to force the loads to reacts on the state of the electric power system. Some advantages of the active load control are:

1. It can reduce the need for future utility investment and generation assets.
2. It can reduces/avoid congestion problems.
3. It reduces peak loads.
4. It can reduce the stress on the network.
5. It can increase the penetration limit for DG units while avoiding large system upgrades.
6. It can increase the penetration limit for DG units while avoiding large system upgrades.

If it is included in a high degree, the load following control strategy could reverse to a more generation following strategy in which the loads accomplish for the extra rigidity introduced at the supply side. Typically loads that might be controlled in e.g. households are loads with a large electrical or thermal capacity and /or inertia like electrical vehicles batteries, refrigerator's, electrical boilers and freezers loads with less stringent timing requirements like dishwashers, washing machines, and dryers.

In general, the introduction of the smart micro grids offers high potential for load response which is enabled by a new smart grid features such as advanced metering ad an embedded communication infrastructure that makes real time pricing possible. Smart microgrids are especially suitable for load response. In order to force the loads to change their consumptions based on the external parameters, the drivers for the load participations should be considered. These drivers can be:

1. Obligatory: The General responsibility to maintain the stability of the system. This driver should be prevented, if possible, but can achieve customer acceptance if it is absolutely necessary for the stability of the system in a small-scale system. If this kind of the driver is necessary to ensure the stability of the system, fast customer response is required.
2. Cost advantages. Customers acquire financial benefits when participating in the active load control.

Communication Based Active Load Control.

The first category of the active load control uses communication to send direct obligatory control signals to the loads or to give loads information about the financial benefits they can achieve when responding to the load control. The drivers for the loads to respond to this information generally comes this information generally comes from the pricing strategy. Therefore, the pricing aspects are briefly discussed...

In general, there are two ways of electricity pricing to promote active load control: incentive based and time-based pricing. In the incentive-based strategy, dedicated control strategy is able to shed load in response to a request from the utility. Incentive based pricing is generally present to deal with emergency based active load control, avoiding outages.

A second category of load response pricing uses time-based pricing. The transmission network and generator are sized to corresponds to the peak demand which involves a capital cost.

Especially time-based active load control is often included to decrease this peak demand, i.e peak shaving, by delivering cost benefits to customers that contributes to this peak reduction. Nowadays, for small consumers (that can be connected to the low-voltage micro grids), a basic time based active load control program exist in the form of different meters.

The single-tariff meter, which is often used, involves a fixed price per KWH, independent of the production cost at the time of consumptions. Therefore, consumers do not face real cost and have no incentives to reduces their consumption during peak times that face high cost of productions. The loads are not sensitive to cost of production in short term. For difference in day versus night consumptions, a situation is brought by the two-tariff meter to lower the costs during nights and weekends compared to the day timed. The three tariff abolished in Belgium charges higher tariffs some hours of the day s e.g. turn on heating.

A newer concept is the smart meter by means of the advanced metering infrastructure (AMI). The main characteristics of this meter is its ability for remote communication. It makes pricing based on real times price possible. This may lead to more market-based pricing strategy. Several real time tariff schemes already exist, such as:

Time of use (TOU) Pricing with different prices defined over a day, with a fixed number of timeslots reflects the average cost of generating and delivering power during those periods. It encourages consumers to shift their consumptions away from periods with high loads to loads with a lower demand with different periods. The prices are typically fixed on a monthly/seasonal basis. This is analogous to two tariff meters, but more differentiation is possible, to cope with seasonal effects.

Real Time pricing. (RTP) with typically hourly varying prices related to the wholesale market prices. Prices are typically fixed on a day ahead or hour ahead basis. RTP allows more graduation in the prices compared to TOU pricing.

Critical Peak Pricing (CPP) uses trigger conditions that can change the price. It is often combined with TOU pricing.

In the smart grid, the number of time slots with different prices and the different price levels can be increased and also, the time the price communicated in advances can be lowered compared to presently running systems. However, there will be a trade -off between the communication burden and number of time slot/different prices/difference between the information exchange and the real time of the usage.

Therefore, it it's difficult to implement this kind of communication based active load control strategies if they are crucial for the stability of the system, e.g in small scale system. Consequently, they cannot be used as primary load control algorithms strategies.

Primary Versus Secondary Active Load Control.

The primary and secondary active load control is based on the primary and secondary control of the generators. In the transmission network. In the transmission system the primary control system is automated based on the rotating inertia of the system, which ensures a constant ratio between frequency changes and production changes and act very fast. The primary control of the centralized generators is performed by an active power /frequency droop control strategy that measures the frequency and changes the input power accordingly. The action of primary control is to restore the power balance an to maintain the system frequency within the specified limits. However the generator adjustment result in deviations from agreed upon power exchanges with a steady state system frequency different from the nominal values. Therefore, secondary control is used to eliminate this frequency deviations and to correct error in the power exchanges programmed between areas.

The primary and secondary active load control in smart microgrids can be considered as an analogous to the primary and secondary control of the generator. The primary active load control is included for reliability issues, preferably, without the communication. The voltage based active load control deals with these conditions. The primary active load control is effective in case of.

1) Islanded micro grids with voltage-based droop control such that high voltages are mainly due to generations from non-dispatchable DG units (renewable energy sources) and low load times.
2) Grid connected micro grids. Non dispatchable DG units (renewable energy sources) can causes overvoltage's during periods of low load and high injections. Generally this is mitigated by conservatively limiting the number of dispatchable DG units.

The secondary active load control can be include for optimization issues, and can operate on a larger time frame. Some of the objectives of secondary load control can be.

1) Communications about the availability of the load: bidirectional information between the smart appliances and the control centres.
2) Emergency actions (direct load control centre).
3) Coordination of the primary ative load control actions.

2. Smart Microgrids

The approach to deal with a large increase of decentralized unpredictable power sources and increasing (peak) consumptions is to add intelligence to the power system. The communication is to add intelligence to the power systems. New communication and remote management abilities help to couple the grid element via a fully interactive intelligent network. The electricity generation, distribution, and consumptions are overlayed with an additional metering and information system to save energy, reduces costs, increase reliability and transparency, and enable more customers choice for their energy management. Essentially, the goal of micro rids and smart grids are the same to minimize cost. Meet the growing demand and integrate more sustainable generation resources, increase efficiency and improve the reliability of the system in the face f increasing intermittency. The micro grid facilitates the penetration of DG into the utility grids as it delivers integration in the coordinated way of dealing with the unconventional behavior of DG. Micro grids offer significant benefits in both the grid perspective decision for clean energy, smart appliance's etc. it can be seems as a micro grid which can ensures a stable operation in the short term and fat acting with an overlaying intelligence schemes that operates slower to restricts the burden and exploits the options of using communications e.g. for economic optimization. Smart microgrids are especially very interesting as they can be considered as small pilot version of the future power system.

A balance between cost to incorporate intelligence and its benefits needs to be made. The infrastructure and the control system for the smart grid can be very hulking to implemented on a very large can take many years, rather than investing in incorporating intelligence on a very large scale, investing in small smart micro grids can be done at a very lower cost and more quickly. This makes smart microgrids very attractive for the implementation of smart grid features. Smart microgrids are thus a simpler alternative and could play a leading role in the deployment of smart network. Also, a high level of intelligence is required built into the system is not necessary everywhere. Different areas require different level of smartness. Areas with merely small residential units requires permits less interferences of intelligent system. While large units benefit more from becoming controllable and areas with higher penetration of DG unit allows higher level of intelligence to increase the maximum DG penetration limit. These areas that allow more and benefits most from high levels of smartness of the system fit directly into the micro grid concept. Therefore, the smart micro grid requires locally more intelligence as compared to the rest of the system.

3. Conclusion

The Smart micro grids enable a coordination control of DG units, active loads, optimized by incorporating more intelligence in the network. The voltage- control of the Distributed generation and operates without communication to ensures proper voltage control, power sharing and balancing, and a stable operation as a micro grid. Therefore, control of the DG in the islanded micro grid. The droop control is based on the specific characteristics of the low voltage islanded micro grid, namely the resistive line impedances, high share of renewables and lack of rotating inertia. The constant power bands to delay the power changes of the renewable energy source as compared to those of dispatchable units without the entire unit communication. This enables an optimum integration of the renewable in the micro grid. It also enables the renewable injection to become visible in the voltage of the network. Therefore, primary active load control is analogous to the voltage-based droop control of Dg as well. The time scale of this active load control is slower than the power changes of the dispatchable units, but faster than those of the renewable, with faster and slower dependent on the terminal voltage's this load control is voltage based. It doesn't require communication and it is very fast. Therefore, it deals with increasing the reliability of the micro grid and is used as a primary control strategy. Smart grid features such as a computational ability and increase usage of communications and sensors can help DG Unit Controller without Communications to optimize the micro grid. In this sense secondary active load control can be used, e.g., for economic operation in case of the emergency situation, or to support the primary control. The drivers for second side is the load change be profit based or time based. Secondary control can be included in an analogous way as proposed in [21].

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