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Power Management Using Hybrid Control of Tie-Converters

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Abstract- **The current power management schemes for interlinked AC-DC microgrids have several operational drawbacks. Some of the existing control schemes are designed with the main objective of sharing power among the connected microgrids based on their loading conditions, while other schemes regulate the voltage of the interlinked microgrids without considering the loading conditions. However, the existing schemes cannot achieve both objectives efficiently. To address these issues, an independent power management scheme is proposed, which explicitly considers the specific loading condition of the DC micro grid before importing power from the interlinked AC micro gridThis method enables voltage regulation in the DC microgrid, and also reduces the number of converters in operation. The proposed scheme is fully independent while it retains the plug-n play features for generators and tie-converters. The performance of the proposed control scheme has been validated under different operating scenarios. The results demonstrate the efficiency of the proposed scheme in managing the power deficit in the DC microgrid efficiently and independently while maintaining the better voltage regulation in the DC microgrid.**

Index Terms- Autonomous control, distributed control, droop control, hybrid microgrids, interlinked microgrids, power management.

I. INTRODUCTION

The technical advancement in power electronics is playing an vital role in the deployment of renewables and alternative energy technologies which have so far been widely realized in different forms of network topologies and configurations. Similarly, they have been controlled and managed using various control strategies and architectures. Their network topologies and control strategies are mainly determined to maximize the benefits while meeting the load requirements. At present, renewable and alternative energy technologies are widely deployed in microgrids. The deployment of these new technologies in the form of a microgrid is preferred due to several advantages such as optimal utilization of resources, improved power quality and enhanced supply reliability. Recently, more advanced grid architectures have emerged including the zone based grid architectures, multi-microgrids, interlinked AC-AC microgrids and interlinked AC-DC microgrids. The main objective of these advanced network architectures is to exploit maximum benefits from renewable and alternative energy resources. For example, by interconnecting two or more microgrids, it will enable reserve sharing, support voltage and frequency, and ultimately enhance the overall reliability and resilience of interlinked microgrids. The interlinking arrangement between two or more microgrids or with utility grids primarily depends on the overall objectives, as well as the control and management scheme used in individual microgrids. The microgrids can be interlinked through harmonizing tie-converters. The harmonizing tie-converters are primarily used when two or more microgrids have different operating voltages and/or frequencies. The tieconverters are also essential if the microgrids to be interlinked have different control strategies and the power flow among them needs to be regulated. Similarly, the interlinking of the DC microgrid with the utility grid or another AC microgrid also requires tie-converters to regulate the power flow among other functionalities, and that has been investigated under various scenarios in the published literature. In, the demand-droop control has been proposed for the interlinking or tie-converters of the AC-DC microgrids. The power flow action is determined based on the normalized terminal voltage and frequency of the droop controlled interlinked AC-DC microgrids. This scheme enables autonomous power transfer between two interlinked microgrids based on their relative loading condition. The power flow decision based on the relative loading may cause the interlinking converter to operate continuously, and thus it may result in unnecessary operational losses. The same power sharing scheme has been extended to interlinked microgrids with a storage system . This scheme is further improved with the progressive auto-tuning to minimize the energy flow through interlinking converters . The proposed auto-tuning enables the power transfer only when one microgrid is heavily-loaded, and another microgrid is lightly-loaded. The droop based power sharing concept has been further investigated for different operating conditions of the interlinked AC and DC microgrids . a hybrid control of tie converters is proposed and the performance is validated under different scenarios.

II. GRID TIE-CONVERTERS

Grid tie-converters are used for the linking of multi-microgrids

1.1 OPERATION:

The power rating of dispatchable generators or storage systems for firming the renewable capacity depends on the variability of the renewable source and loads in the microgrid. The high variability of renewables and loads requires dispatchable generators or storage systems with a high power rating, which may or may not be a efficient solution. Alternatively, the microgrid with inadequate generation capacity could be interconnected with another microgrid or utility grid, directly or through harmonizing converters. The tying of a DC microgrid with a AC microgrid or utility grid is only possible through tie-converters. In the given scheme interlinked system, the AC microgrid is characterized as a regulated voltage and frequency system with adequate generation capacity, whereas the DC microgrid is characterized as a droop controlled system with inadequate generation capacity due to the high variability of the renewable and loads. During the peak demand or the low renewable power output, the power deficit in the DC microgrid is managed by importing power from the AC microgrid. Ideally, it can be achieved efficiently and autonomously with the proposed control of the tie-converters. In summary, the control scheme of the tie-converters is developed based on the following objectives: 1) To share power from the AC to DC microgrid during the peak load demand or generation shortage in the DC microgrid; 2) To reduce the power transfer losses, e.g., tie-converter should operate only during the peak-load demand in the DC microgrid, and the number of tie-converters in operation should be based on power transfer demand; 3) To control the voltage of the droop controlled DC microgrid; 4) To achieve fully independent control without depending on the communication network; 5) To enable the plug-n-play feature for tie-converters and generators.Unlike the existing schemes for the interlinked AC-DC microgrids , a hybrid droop and voltage regulation mode control is proposed for the tie-converters and the mathematical form of the proposed control scheme.

2.2.CONTROL OF TIE-CONVERTERS:

Vdc,ref,TCx =

1.Off; Vdc > Vdc,start,TCx

2.Vdc,start,TCx − δL,TCx × Pdc,TCx;

0≤ Pdc,TCx ≤ L% × Pdc,max,TCx

3.Vdc,nom,TCx;

L% × Pdc,max,TCx<Pdc,TCx < (100−H)%×Pdc,max,TCx

4.Vdc,nom,TCx−δH,TCx[Pdc,TCx−(100−H)% Pdc,max,TCx];

(100 − H)% × Pdc,max,TCx ≤ Pdc,TCx ≤ Pdc,max,TCx

where TCx represents the tie-converter number (x = 1, 2, 3..)Vdc is the DC microgrid voltage; Vdc,ref,TCx is the reference voltage of xth tie-converter; Vdc,start,TCx is the threshold voltage to start of xth tie-converter; Vdc,nom,TCx is the nominal voltage to be regulated by xth tie-converter; Pdc,TCx is the DC power output of xth tie-converter; Pdc,max,TCx is the maximum power limit of xth tie-converter;

L % and H% are the percentage of tie-converter rated power allocated for droop1 and 2 mode, respectively; Vdc,nom,TCx+1 is the DC microgrid voltage when xth tie-converter transfers maximum power; δL,TC(Vdc,start,TCx−Vdc,nom,TCx)/(L% × Pdc,max,TCx) is the droop 1 gain (at low power) of xth tieconverter; δH,TCx = (Vdc,nom,TCx − Vdc,nom,TCx+1)/(H% ×Pdc,max,TCx) is the droop 2 gain (at high power) of xth tieconverter.

III.DC AND AC MICRO-GRIDS

3.1.CONTROL MODE OF DC AND AC MICROGRIDS

The considered DC microgrid includes a non-dispatchable generator (solar-PV) and dispatchable generators (micro turbine, fuel-cell) and loads, as shown in Fig. 1. The non-dispatchable- solar PV system is set to operate in current control mode and thus extracts maximum power at all the times. The dispatchable generators are typically used for firming the renewable capacity and can be controlled either through a centralized or decentralized control scheme. Decentralized droop scheme is the most widely used and preferred, as it is simple and reliable. Therefore, the traditional droop (P-V) scheme has been used for the dispatchable generators of the DC microgrid (see Fig. 1), which is given by

$$V_{dc,ref,i} = V_{dc,max} - \partial_{dc,i} P_{dc,i}$$

$$\partial_{dc,i} = \frac{V_{dc,max} - V_{dc,min}}{P_{dc,max,i}} = \frac{\Delta V_{dc}}{P_{dc,max,i}} \quad (1)$$

where, i is the DC generator number (i = 1, 2, 3. . .); $V_{dc,ref,I}$ is the reference voltage of ith generator; $P_{dc,i}$ is the output power of ith generator; $V_{dc,max}$ and ($V_{dc,min} = V_{dc,nom,TC1}$) are the defined maximum and minimum voltage; $P_{dc,max,i}$ is the maximum or rated power of ith generator; and $\partial_{dc,i}$ is the droop gain of ith generator. Based on (1), the voltage reference for the droop controlled generators 1 and 2 can be calculated by (2) and (3). As generators 1 and 2 share common DC bus voltage (i.e., $V_{dc,ref,1} = V_{dc,ref,2}$), (2) and (3) can be equated and rewritten by (4), which demonstrates that the droop controlled generator will share proportional power according to their rated power capacity.

$$V_{dc,ref,1} = V_{dc,max} - \partial_{dc,1} P_{dc,1} \quad (2)$$

$$V_{dc,ref,2} = V_{dc,max} - \partial_{dc,2} P_{dc,2} \quad (3)$$

$$\partial_{dc,1} P_{dc,1} = \partial_{dc,2} P_{dc,2} \rightarrow \frac{P_{dc,1}}{P_{dc,max,1}} = \frac{P_{dc,2}}{P_{dc,max,2}} = \frac{P_{dc,i}}{P_{dc,max,i}} \quad (4)$$

The equality in (4) is based on the fact that the voltage at the generator terminals is the same. Practically, the voltage at all the generator terminals is not the same due to the fact that they are connected through feeders/cables of different lengths. This voltage mismatch at the generator terminals affects the power sharing accuracy, which needs to be compensated by using any of the appropriate compensation methods . The droop equation with compensation of the feeder voltage drop can be rewritten by

$$V_{dc,ref,i} = V_{dc,max} - \partial_{dc,i} P_{dc,i} + i_{dc,i} X_i. \quad (5)$$

The voltage of the droop controlled DC microgrid will vary with the changing load, but within the defined permissible range. With the proposed hybrid control (droop and voltage control mode), tie-converters autonomously transfer power from AC to DC microgrid when the load demand in DC microgrid is high and all generators are heavily loaded (stable threshold).

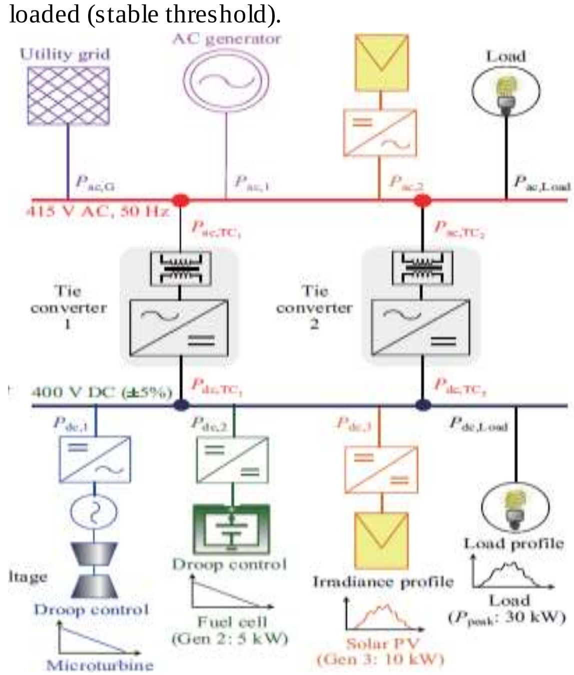

Fig.1.interlinked microgrids

TABLE 1: Control modes

ENTITY	CONTROL MODE	
AC MICROGRID	Islanded-microgrid with regulated voltage and frequency Grid-connected mode	
TIE-CONVERTERS	hybrid droop and voltage control	
DC MICROGRID	DISPATCHABLE	droop
	NON-DISPATCHABLE	MPPT

3.2.PERFORMANCE VALIDATION

A .Scenario :DC microgrid with variable load

The DC microgrid comprises micro turbine (Pdc,max,1 =10 kW), fuel cell (Pdc,max,2 = 5 kW) and variable DC load (P Load, peak = 20 kW) and it is interlinked with the AC microgrid through a tie-converter (Pdc,max,TC1 = 10 kW). The load in the DC microgrid is varied in steps from 5 kW to 20 kW (i.e. 5 kW → 10 kW → 15 kW → 20 kW → 10 kW). At the 15 kW load demand, the expected loadings of generator 1 and generator 2 are more than 80%, and the voltage of the DC microgrid is below the set threshold of Vdc,start,TC1 = 402.5 V. This condition will enable the tie-converter 1 to import power from the AC microgrid and regulate the voltage of the DC microgrid at the defined nominal value of Vdc,nom,TC1 = 400.0 V. performance can be witnessed from the results shown in

At the highlight point 1, at 8 s, the voltage of the DC microgrid decreases below 400 V followed by the step load change from 10 kW to 15 kW

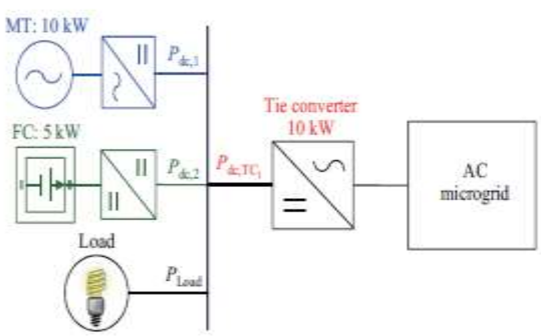

Fig.2.Scenario 1

B.Scenario 2:Non-dispatchable generator and load profile

A non-dispatchable generator–solar PV system is added to scenario 1, as shown in The power output of the solar PV system is based on a continuously varying irradiance profile. The load in scenario 2 also has a varying profile with a peak demand of 25 kW. This test scenario is developed to further demonstrate the effectiveness of the proposed strategy for various practical operating conditions of renewable generation and load demand The load in the DC microgrid increases gradually to the peak value 24.5 kW, and then decreases, The loading on the DC generators increases with the increasing load demand. At the highlight point 1, the loading on generator 1 and generator 2 exceeds 80% and the voltage of the DC microgrid drops below the set threshold of Vdc,start,TC1 = 402.5 V when the load demand is very high and the solar PV output is less. In agreement with the proposed control, tie-converter 1 starts at highlighted point 1 and imports power from the AC microgrid to overcome the power deficit in the DC microgrid while regulating its voltage. Tie-converter 1 operates in the voltage regulating mode from point 2 at 8.5 point 3 at 14.2 s. From point 3 and onward, the load in the DC microgrid deceases such that the tie-converter power output is below 10%×Pdc,max,TC1 and this condition requires the tie-converter to operate in the droop 1 control mode before it turns off at highlighted point 4 at 16.4 s. From point 4 and onward, the load demand in the DC microgrid is less than the generation, hence it can be met by the local generators. As expected, it has been demonstrated that the tie-converter only operates during the power deficit in the DC micro grid. we cannot entirely depend upon these criterias but to make it more efficient and effective just by the hybrid control of tie-converters.the tie converters serve the purpose of interlinking the microgrids as well as the voltage regulation purpose. It imports power from the ac microgrid and transfers it to the dc.

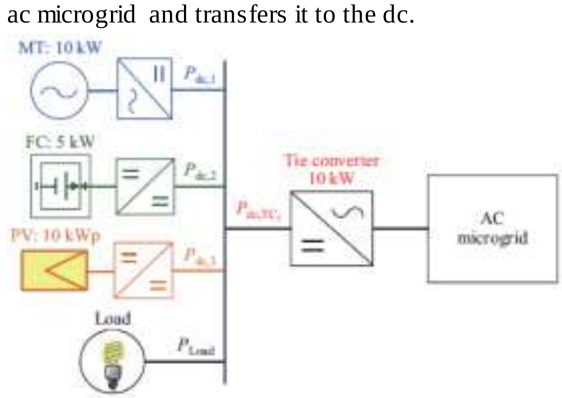

Fig.3.Scenario 2

IV.RENEWABLE ENERGY UTILIZATION IN GRIDS

Renewable energy is energy that is collected from renewable resources, which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat. Renewable energy often provides energy in four important areas: electricity generation, air and water heating/cooling, transportation, and rural (off-grid) energy services. Renewable energy accounts for around 22% of global power generation, but this share is expected to double in the next 15 years, partly due to the rapid growth of variable renewable energy from solar photo voltaics and wind. This IRENA/IEA-ETSAP Technology Brief provides an overview of the main performance and costs of technologies that are used to support renewable energy grid integration, an overview of the shares of variable renewable energy across the world, and existing operational experiences in continental and island systems. There are several technology options available that can help integrate variable renewable energy into power systems. Furthermore, new advances in wind and solar technologies allow them to be used over a wider range of conditions. In the longer run, however, power systems with high shares of variable renewable power generation will require a re-thinking the traditional designs, operations, and planning practices from a technical and an economical point of view.Two immediate applications for innovative technologies and operation modes for the integration of high shares of solar photovoltaics and wind are in mini-grids and islands. Furthermore, any economic analysis of the transition towards a renewables-based system should always consider the total system costs, including social and environmental benefits

Fig.5. statistical analaysis

V.CONCLUSION

An independent power scheme for power management in the interlinked microgrids was proposed and was found to be an effective and efficient scheme. The existing or the current power controlling schemes are either based on loading criterias or either based on voltage regulation but the proposed scheme which is the hybrid control of tie-converters does the purpose of both by power management using loading as well as it regulates voltages to a nominal voltage level value in the DC micro grid. The renewable energies are the major source for this microgrid and so the energy output from these should be effectively and efficiently managed. The number of tie converters in operation has been reduced with the proposed prioritization to avoid unnecessary operational losses. The scheme has demonstrated better voltage regulation in the DC microgrid. The performance and robustness of the proposed scheme have been validated for two different scenarios of the DC microgrid at variable load conditions.

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