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Stabilising the Voltage and Frequency of AC to HVDC Micro Grids

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ABSTRACT

Grids are simply networked interconnections that allow electricity to be delivered from producers to consumers. Renewable energy sources are critical components of power systems, particularly microgrids. This type of grid is installed near the coast to transfer power from one island to the next. However, the power generated by renewable sources is unstable. The frequency stability of the system will be adjusted as a result;therefore some coordinated techniques and approaches were established to resolve this.The proposed Adaptive voltage droop management model with power-sharing ability increases frequency stability and keeps AC voltage stability of the AC/HVDC power network, according to the small-signal stability analysis.Another technique was also suggested, which combined voltage droop control with virtual parallel impedance.

This work describes how to stabilize the voltage and frequency of AC to HVDC microgrids using several types of control systems, including a multidimensional droop control technique with adaptive droop control with power sharing and virtual impedance method.

Keywords:VSC-HVDC; multilevel HVDC; stability; modular multilevel converter; line commuted converter; control strategies; adaptive voltage droop method; power sharing; DC voltage deviation; parallel inverter; virtual impedance; negative resistance.

1. Introduction

In order to reduce greenhouse gases brought on by the power generation, renewable energy sources are being utilised in power systems more and more.Wind, tidal, and solar energy sources will be located far away from load centres. As a result, for long-distance transmission, HVDC transmission systems are used for remote locations or islands [2]. This system wisely switched transmission to grids. This grid is now utilized for efficient power transfer. Power electronic converter systems (also known as VSCs) areutilized in this grid, and these controller devices will differentiate the critical dynamics between connected AC power grids [3][4]. It is critical to developing strategies for ensuring the oscillatory stability, voltage, and frequency of the AC/MT-HVDC power grid.

The various techniques used to maintain the required parameters are as follows:

1. Master-Slave control [5].
2. DC voltage droop control [6].

1.1. Master-Slave control

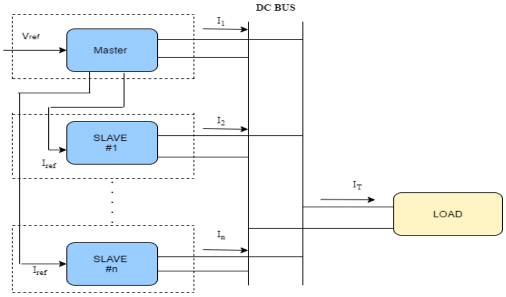

Fig-1 Master-slave control

Fig-1; demonstrates about the master-slave control bock diagram Each block is made up of a static converter, a DC source, and a controller. The Master block, which initially controls its voltage on the DC bus bar, is the most vital block. The others are propelled by the current, but they are slaves.

The main disadvantage of the system is that it requires a low latency channel because the master block provides a current signal as a reference.The master block has the power to cut off the entire system if there is any communication delay.

2. Voltage droop control

Figure 2demonstrates about the diagram scheme of the voltage droop control scheme. As the given current increases, each droop control mimics an impedance behaviour and drops the converter output. This approach encourages current distribution among parallel converters connected in DC microgrids without the need for centralized control.

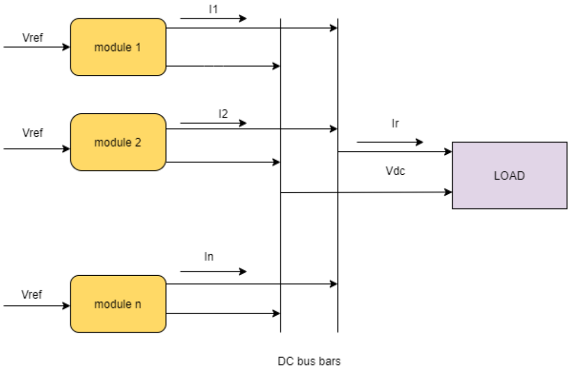

Fig -2 voltage droop control

Droop control, as opposed to master-slave control, avoids the dependency on a single controller. The voltage control is shared among multiple converters in a bus bar network using this method. The ability of DC voltage droop control to function as a distributed control scheme distinguishes it significantly from other techniques. As a result, every converter in the circuit is given the same value and is ready to participate in voltage stability at the same period. When compared to master slave control, voltage droop control has the following advantages: (1) the circuit can work at the time of converter output; (2) After some interruptions, DC voltage can be efficiently controlled; (3) There is no requirement for a communication channel, which avoids control issues caused by communication lag.

Recently, improved methods of DC voltage control structures have been implemented:

Power-sharing capabilities with adaptive voltage droop control [7].

combined voltage droop control technique with virtual parallel impedance [20].

2.1. Power-sharing capabilities with adaptive voltage droop control

Figure 3 depicts the fundamental design and operation of a VSC-HVDC station. The two cascaded control loops that make up a VSC HVDC station's control system are the outer control loop and the inner current control loop. The inner current-control loop (voltage oriented) is implemented in the synchronously rotating DQ-frame and enables the dq-frame current (I_d, I_q) to accelerate the current reference (I_{dref}, I_{qref}) by modifying the output voltage of the VSC. The inner current loop control directly governs the current and power in the VSC in line with the references created by the outer loop control. The inner current control loop gets current references and operates on the converter's output voltage. By regulating the voltage coupling compensation and feed-forward compensations of the AC voltage in the inner current control loop, the current in the dq-frame may perform decoupling control.

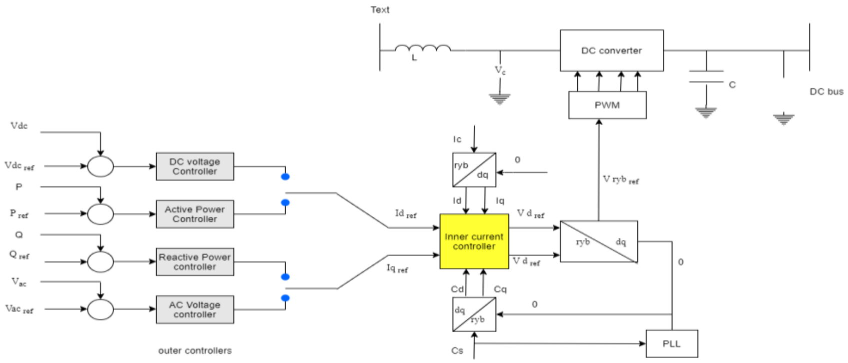

Fig-3 voltage source converter

The outer controller is essential for providing the DC power and voltage of the VSC, which serve as the inner control loop's reference values.Depending on the power modes and DC voltage described in the next sections.The constant voltage, constant power, or droop controllers produce the required number for the active-current (I_{dref}), whereas the reactive-power or AC voltage controllers provide the required number for the reactive-current (I_{qref}).There are different modes in VSC-HVDC they are:

- **Constant current control mode**

  This control mode is a combination of constant current mode and constant power mode. Based on the DC voltage, it tries to balance the power going to its reference.
- **Constant power control mode**

  The converter's power flow remains in the constant power control mode irrespective of the terminal's voltage level. P will eventually reach the reference power pref.
- **DC voltage control mode**

  The const. voltage control mode keeps a stable DC-voltage at the terminal when unexpected change in power flow occurs. And after that the voltage V_{dc} will eventually approach the reference voltage Vdc_{ref}

Now, R_{droop}represents the dc voltage response and the units are MW/KV. For both the Const. Power Control Mode and the Const. DC Voltage Control Mode, the DC voltage controller provides the Const. parameters. When, $R_{droop}=0$, Therefore, droop control is considered as constant power control. $R_{droop}=\infty$, Therefore, droop control is considered as constant DC voltage control. So, by this, we can vary the droop co-efficient (R_{droop}) for different operating conditions required for the VSC controller to achieve power sharing and voltage deviation.

The i^{th} VSC converter's DC voltage response R_{droop} is equal to its volume. As unexcepted circumstances like breakdowns or station service interruptions occur, converters with fixed droop control may experience power and DC voltage oscillations that are beyond their limitations. This issue can be resolved with the use of adaptive droop control.

2.2. Adaptive Droop control

In a fixed control scheme, the droop coefficient mainly depends on the converter's outage. Under certain operational conditions, all converter stations with droop control might become saturated and exceed their limit. A low R_{droop} signifies that the controller is power-restrictive, providing for small power fluctuations in the case of a large Vdc fluctuation. A significant R_{droop} indicates a voltage-strict controller that will not permit a significant Vdc oscillation for a considerable power variation. [16].

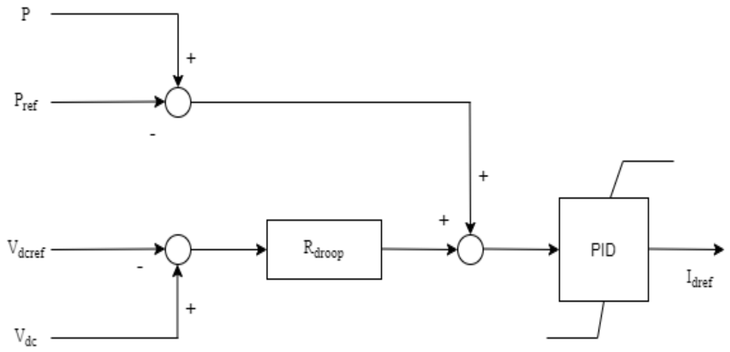

Fig-4; fixed adaptive controller

Based on the operational status of the converter station, the DC voltage response coefficient will change.By using this technique, it will be prevented for converters that are close to their power limitations from attempting to share the imbalanced power, and converters lowering their DC voltage limitations won't attempt to undermine the ability to adjust DC voltage for power sharing.

2.3. Combined voltage droop technique with virtual parallel impedance

parallel inverters play a vital role in distribution circuitsand also in uninterrupted power supply (UPS). As a result, for these applications, excellent power-sharing percentage and the suppression of circulating current are required. Thus, the droop control method is better to the inverter's output impedance. However, the optimum performance may only come from pure resistance or pure inductance.The inverter's output impedance is thus superior to the droop control strategy, but only pure resistance or pure inductance may provide the greatest performance. [17,18]. So, to resolve this issue a new technique was implemented along with virtual impedance a negative resistance was used in the circuit. With this method, the circulating current between the inverter would be controlled and the output impedance would be pure inductive which increases the load-sharing accuracy.

In general, the reactive power (Q) and active power (P) are both totally dependent on the phase and amplitude differences, respectively.

$$F=f^*-mP;$$
$$U=U^*-nQ;$$

f^* is output voltage frequency U^* is the amplitude at no-load, *and m* and *n* are the frequency and amplitude droop co-efficient.

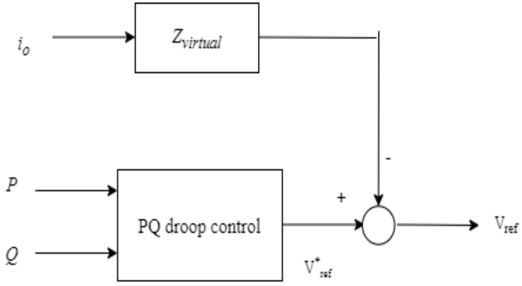

Fig-5 block diagram of virtual impedance implementation

This leads to the conclusion that the droop control approach for a parallel inverter is effective. But within this, there are several concerns that need to be addressed.:resistance should be negative as mentioned and also it should not affect the load-sharing accuracy [19]. The controller parameters can affect the inverter's output impedance. To overcome these disadvantages, virtual impedance was introduced. this virtual impedance works in changing the output impedance to desired or rated values.

- **Resistance Virtual impedance:**

  If the value of Z_{vitual} =$R_{virtual}$, then the impedance is purely resistive. The phase-frequency characteristic reveals that the inverter's output impedance resembles pure resistance, whereas the amplitude of the output impedance increases as the virtual impedance increases.

- **Inductance Virtual impedance:**

If the value of Z_{vitual} =$L_{virtual}$, then the impedance is purely inductive. The phase-frequency characteristic reveals that the inverter's output impedance resembles pure inductance, whereas the amplitude of the output impedance increases as the virtual impedance increases.

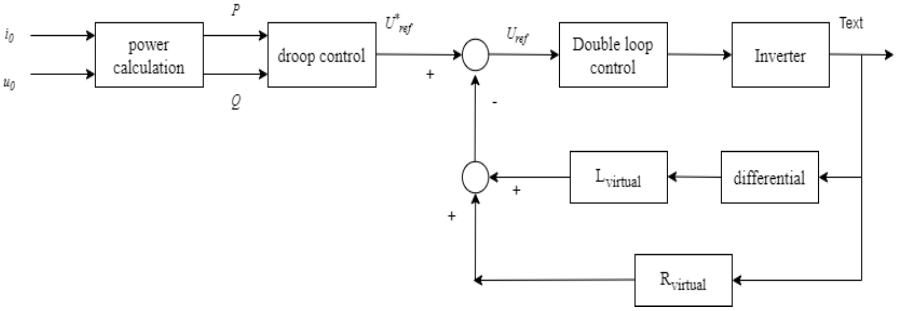

Fig-6 block diagram of proposed virtual impedance

With these results, the virtual impedance method improves the load-sharing accuracy between parallel inverters. A voltage drop is often the result of a resistive virtual impedance, but an inductive virtual impedance causes an output phase delay.To correct this a pure inductor and a resistor is connected to the circuit. The output impedance will be inductive as a result, improving the angle between active and reactive power. it weakens the currents that are circulating.

3.Conclusion

This paper illustrates the different types of techniques used and the modified schemes or connections for maximum output. The purpose of this system was to maintain stability in the AC voltage, AC frequency, and DC voltage.Additionally, it shows that the suggested control methods greatly increase oscillatory stability when compared to the conventional droop control method. Additionally, anunique virtual impedance technique that enhances the wireless connection of parallel inverters by using pure inductance and negative resistance was also addressed.

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