Application of Virtual Synchronous Generator for Future Power Systems

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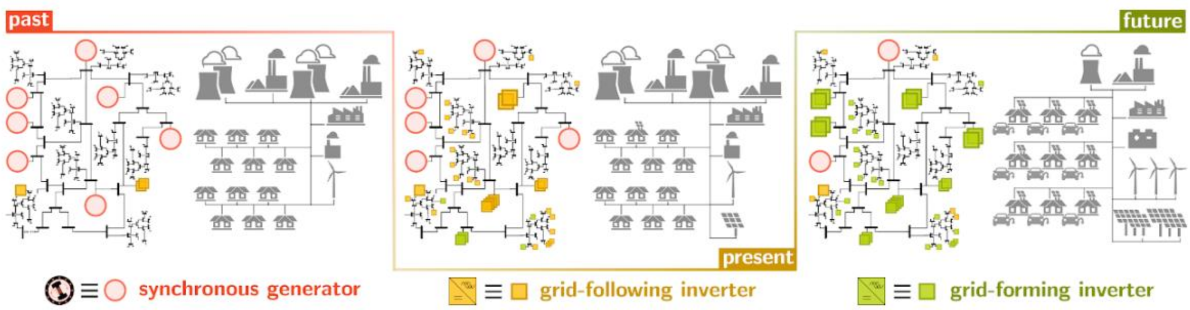
I. Research Background and Objectives

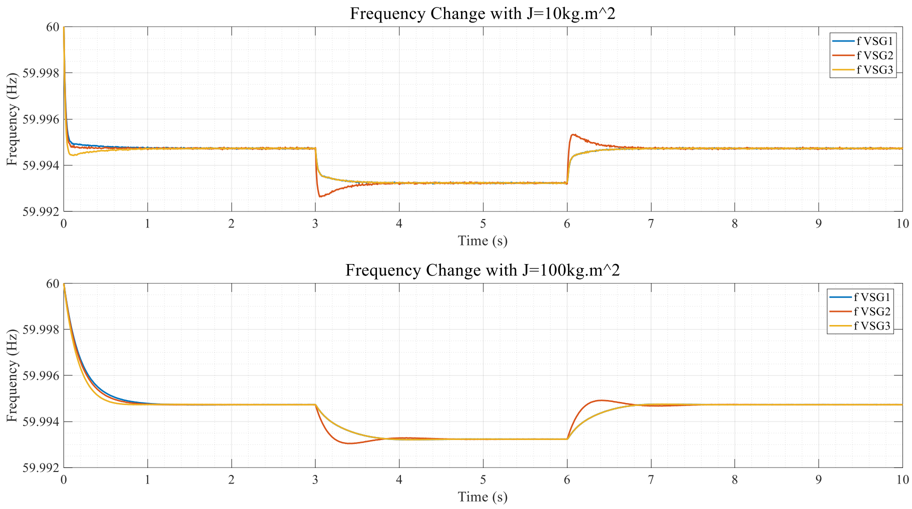
In recent years, due to the increasing penetration of renewable energy, the proportion of inverters in power systems has gradually increased, as shown in Fig. 1. Therefore, the number of traditional synchronous generators decreased, resulting in a decrease in the inertia of the power system. However, inverter-based resources do not have the moment of inertia and damping effect. When the power system is disturbed, the stability of the power system will have a greater impact. Based on the above mentions, by combining the swing equation of the traditional synchronous generator with the inverters, the inverters can simulate the dynamic characteristics of the traditional synchronous generator, which is called a virtual synchronous generator (VSG). VSG is a grid-forming inverter with the characteristic of providing inertia, which can be used to overcome the problem of low power system inertia when the penetration of renewable energy is high in the future. By simulation analysis, when the power system is disturbed, VSG can suppress the rate of change of frequency (RoCoF), so it is suitable for power systems with high penetration of renewable energy in the future.



（Source：https://sites.google.com/view/unifi-consortium/home）
Fig. 1 Future power system development trends

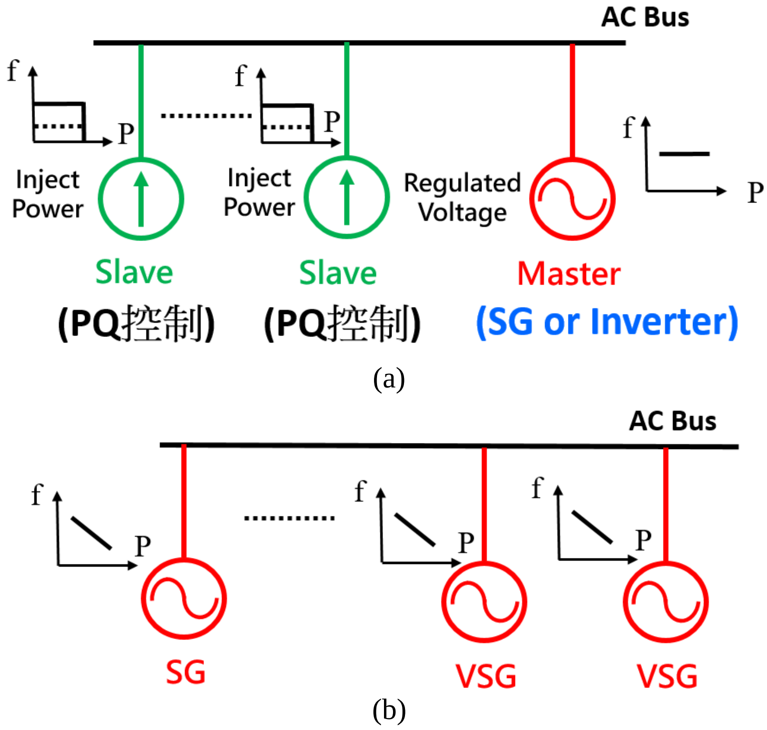
II. Research content

Fig. 2 shows RoCoF with different inertia constants; it can be seen that RoCoF can be changed by adjusting the inertia constant of the VSG. Therefore, when VSG is applied in the power systems in the future, the appropriate inertia constants need to be adjusted for different power systems. Fig. 3 shows the application architecture diagram of the inverters in the power systems. Fig. 3(a) shows a master-slave architecture, and Fig. 3(b) shows a peer-to-peer architecture. In the mater-slave architecture, the master can be a traditional synchronous generator or an inverter with V/F mode. The slave is a grid-following inverter with P/Q mode. However, the disadvantages of the master-slave architecture include high dependence on the master and poor reliability. When the master fails, the slave will not be able to operate. In the peer-to-peer architecture, each inverter has equal status and no distinction between master and slave. If the inverter runs in VSG mode, it can co-work with the traditional synchronous generator. Therefore, when one of the generators or VSGs fails, other generators or VSGs can autonomously share power distribution without communication and can be plug and play. In the future, VSGs can operate in coordination with traditional synchronous generators. The output power of VSGs can be increased, thereby achieving net-zero carbon emissions and stabilizing the power system.



(Source: drawn by authors)

Fig. 2 Relationship between output frequency and output power of VSG



（Source：drawn by authors）

Fig. 3 Architectures of applications of inverter in power systems

III. Conclusion

As the proportion of renewable energy gradually increases, low inertia and low damping will affect the stability of the power systems. Therefore, by combining the swing equation of the traditional synchronous generator with the inverter, the inverter has the dynamic characteristics of the traditional synchronous generator, which is called a virtual synchronous generator (VSG). VSG can be used to overcome the instability problem of the power system as the proportion of renewable energy increases. VSG has the characteristic of providing virtual inertia, which can suppress RoCoF when a disturbance occurs in the power systems. Therefore, when the proportion of renewables in future power systems becomes higher, VSG is a feasible solution to replace the traditional synchronous generator. VSG is a relatively new power electronic control technology, and there is still a lot of research to be done, such as the transient response, fault ride-through, and coordination issues between VSGs of different brands.