Hybrid Power Distribution Substation with Flexible AC and DC Power Flow

David Praise Princhan
B.Tech Student, Electrical and Electronics Engineering Dept., A P J Abdul Kalam Technological University, Kerala, India

***Abstract*- There is the developing trend in the AC and DC hybrid power distribution network. For the enhancement in flexible operation capability of the AC and DC hybrid power distribution system we need to design a flexible substation. Here we discussing about the designing of such a flexible substation. The system is consisting of such devices which are capable to handle with the AC and DC high or low voltage and also with different level conversion of voltages. Hence the system has the advantage of voltage transformation, electrical isolation between different levels of voltages. It also can achieve the realisation between the grid and load side power flow control. Here we discuss the general topology and working of individual parts in the system and their functionality in detail.**

Index Terms- flexible substation; AC/DC; hybrid power distribution; controlling.

I. INTRODUCTION

There is the rapid development in distributed generation, availability of energy storage devices and the power electronic technologies, the distributed regenerative power generation in the user side also increasing also with the increase in technology and demand. Day by day the number of consumer and the demand for power such as distributed energy storage, DC loads and AC loads increasing. Therefore, there is a growing demand for two-interaction between the grid and user, high voltage and medium voltage distribution network, medium voltage and low voltage distribution network.

In the existing system for implanting these newly developed technologies is not that much successful. When we look in to the conventional power system the entire feasibility in the system was done by only with any one type of the power transfer. The traditional AC power distribution has some limitations on comparing with AC/DC hybrid power distribution. If we implementing a new system in accordance with to the existing we should convert the form of produced energy into different to include this into the transmission level. For that, we have to give converting units in individual production units. By introducing AC/DC hybrid we can avoid such converting units and reduce the cost loss of conversion in the system. Hybrid power distribution system has the advantages of no instability problems, transmission efficiency is high, reliable regulation, and saving power transmission corridor. The conventional power distribution network uses the AC distribution network, which mainly work for voltage conversion between different voltage levels and fault protection. The system we discuss here can achieve the voltage conversion in different levels of voltage and in different types, but for to achieve flexible operation capability of the network it should be need to consider the power flow control issues in entire AC and DC hybrid distribution network. Because of the limitation in conventional substation when applied into AC and DC hybrid distribution network we have to adapt a more complex AC and DC hybrid distribution network, to develop such a complex generation network we introducing much more dense power electronic devices with a high level of technologies.

This paper focused on the problems when designing the AC and DC hybrid substation and distribution network. For the newly introduced system which have implementation and designing of improved power electronic technologies. The flexible substation consists of high/low voltage AC ports and high/low voltage DC ports. On comparing with the traditional substation it has the feature of voltage transformation and electrical isolation as in the existing system, what is more in the system is that it can realize the power flow control between the grid

side and load side only with local control methods. The topology and the basic operation principle of flexible substation are analysed and for ensure the effective and stable operation of entire system the corresponding control strategies are also designed.

II.BASICS IN FLEXIBLE SUBSTATION

2.1. Topology

The circuit topology of the flexible substation is shown in the fig.1. The working based structure is given here, the conversion of high voltage AC into high voltage DC is the first step in its working. The user side loads and the distributed generations are connected in low voltage side. The main components in the system

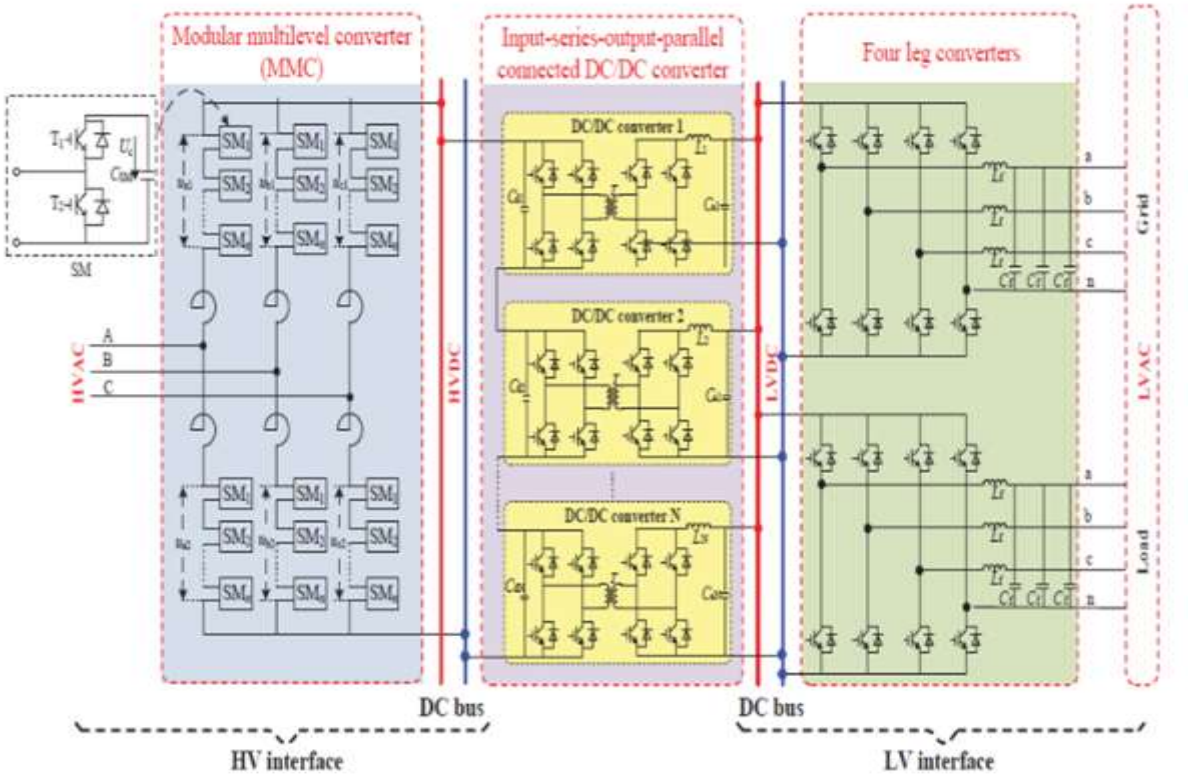

Fig.1. Topology of flexible substation

are modular multilevel converter (MMC), bidirectional isolated DC/DC converters and four leg AC/DC converters. The bidirectional isolated DC/DC converters are connected with input series and output parallel (ISOP) mode.

In this flexible substation system, the different important components were doing there functions. The MMC work as n inverter and convert high voltage AC to high voltage DC. The electrical isolation between HVDC and LVDC is done ISOP and it converts the HVDC to the low voltage dc level. Four-leg converter connects the LVDC to LVAC line and the required AC/DC voltage output is gives. By using different converters we can choose either single phase or three phase line outs.

2.2. Structure of AC and DC hybrid power distribution system

A typical diagram of AC and DC hybrid power distribution system is given in fig.2. The flexible substation is provided by four different bus ports and they connected with grid and other for the distributed generation and to various loads. The DC grid is connected with HVDC and AC grid is connected to HVAC port because these are high tension lines available in the system. The DGs produce AC voltages and loads require AC voltage are connected with LVAC port. This will make the system more user friendly system with good reliable services. By using better controlling devices in the control panel of the system we are able to drive the system under

off grid state also, so the overall better utilisation of energy is possible.

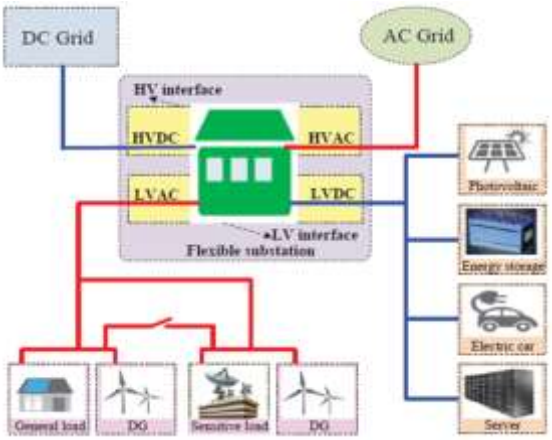

Fig.2. Diagram of AC/DC hybrid distribution network with the flexible substation

The photovoltaic systems, energy storage batteries and the loads require DC supply are connected with the LVDC port in flexible substation. Here the different networks in AC and DC hybrid distribution system are supported each other and the stability of entire system can be enhanced. By this type of systemthe user side and the grid side synchronization can be obtained.

III. HVAC PORT TO HVDC PORT CONTROL

The conversion from high voltage AC to high voltage DC is done by the help of a modular multilevel converter. In a MMC we have sub-modules in each phase and they were connected series in phases.

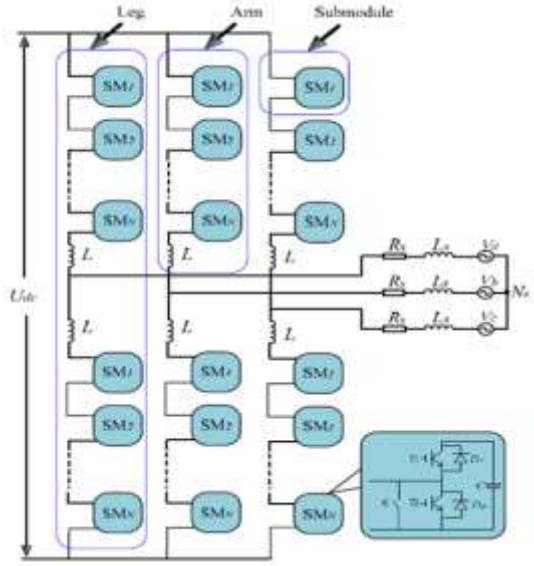

Fig.3. Modular multilevel converter

The MMC adopt the closed-loop control strategy, which is specific and is based on the outer ring of DC voltage and the inner AC voltage ring control. The control block diagram is shown in fig.4.

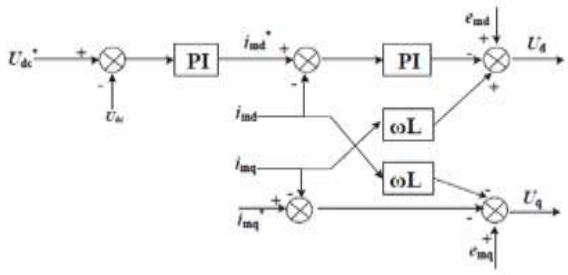

Fig.4. Double loop control block diagram

Outer loop control according to different control targets generates d axis and q axis reference value of current component; and inner control achieves independent control of d axis and q axis current component which follow outer loop reference value. Through the double closed loop control mentioned above to generate three phase modulation wave, and the inner loop current decoupling controller is designed as the station control part.

The sub-modules in MMC have the capacitors connected with them the output power quality in the system is based on capacitor voltage state. The difference in capacitor parameters, characteristics of semiconductor switching devices, sub-module charging and discharging and drive pulse asynchronous where affect the quality of output power.

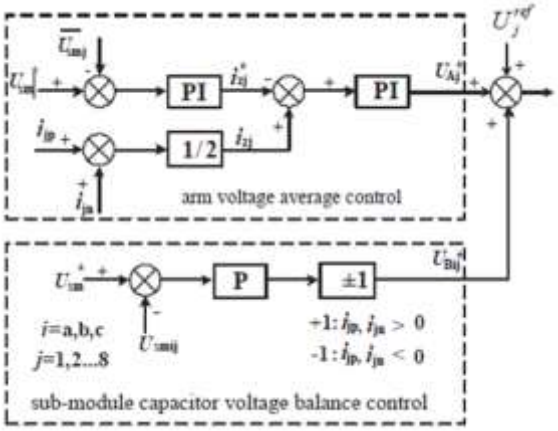

Fig.4. Capacitor voltage control

IV. HVDC PORT TO LVDC PORT CONTROL

It is achieved by the use of an input series output parallel DC/DC converter. Here this is useful for

achieving electrical isolation between high-voltage DC to low-voltage DC line. The interfacing of different distributed generation systems can also do in the low-voltage DC bus.

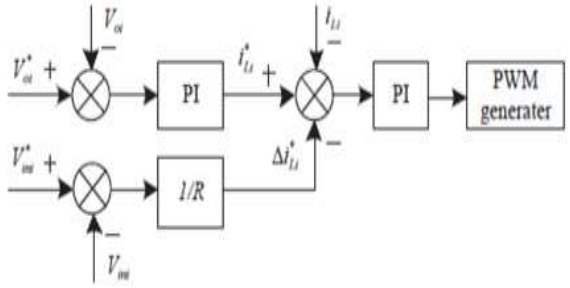

Fig.5. Drop voltage sharing

The converter works to convert high-voltage to low-voltage level DC voltage and to improve the reliability of the system the drop voltage sharing control technique has to be used. The challenge in the ISOP converter is to ensure that each module shares the input voltage and load current even in the presence of substantial differences in various module parameters.

V. LVDC PORT TO LVAC PORT CONTROL

The research on hybrid AC/DC power system mainly focuses on topology design, operation control strategy, fault protection and stability analysis. Mainly describes several designing principle of distribution network according to the partition and hierarchy principles, while consider resource utilization maximization, energy complementary, energy storage and reactive power compensation. The corresponding power control strategy is comprehensively expounded in three components, which include AC subsystem, DC subsystem and interlinking converter. The state-of-the-art power control strategies of AC and DC subsystem are classified and summarized, hierarchical control is more popular in all of the control, which can not only sharing the load current, but also providing virtual inertia for the system.

The AC to DC converter is used here for the conversion of LVDC port to the LVAC port. By using a suitable converter the single phase or three phase supply line out is get from the load side. Basically here the system consists of two modes of operations, which are grid operation and the off-grid operation. In this low voltage ports we can interface the home appliances successfully. We are available with photovoltaic cells and other DC renewable energy storages equipments, so the connecting them into the system is very simple.

5.1. Grid operation mode

Under grid operated mode of operation the output is connected to the AC power grid. The entire demand is carried out by the AC grid at the time there all the supporting systems such as distributed regeneration and the energy storage devices are absent or every devices are work as the loads. In grid operated mode of operation the control strategy adopted is constant power control. This control strategy is based on the closed-loop vector control of the inductor current under synchronous rotating coordinate system.

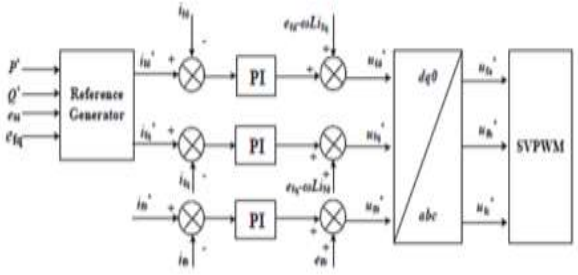

Fig.6. Block diagram of constant power control

The control block diagram is given above fig.6.the control strategies over the switching devices are done based on the SVPWM result from the system control loop. From the reference values and the system out generated by analyzing these required control signal for the system is to be created. The d-q axis representation of the system is then converted to a three variable system before it giving to the SVPWM because the control we have to done in a three phase system. The inductive current closed-loop feed-forward decoupling strategy based on PI controller is adopted to realize the independent control of the system active reactive power.

5.2. Off-grid operation mode

In off-grid mode of operation the output directly supplies the power to load. So the output voltage and frequency should be maintained stable with constant AC voltage control. All the available distributed energy sources and the production units are in action. Because of the interfacing done on different individual units to the system there will be a problem for synchronization of available power. Under off-grid mode of operation the unbalanced voltage

contains negative and zero-sequence components. In the positive sequence dq coordinate system, it will cause twice and fundamental frequency fluctuations. If the traditional PI control method is still used to adjust the voltage of negative- and zero-sequence components, the output AC voltage cannot maintain the balance. Therefore, the positive and negative sequence voltage control in double dq coordinate system is adopted. The feedback voltage is transformed to the positive sequence and negative sequence dq coordinate system, and the fundamental zero sequence voltage is suppressed by the PR regulator.

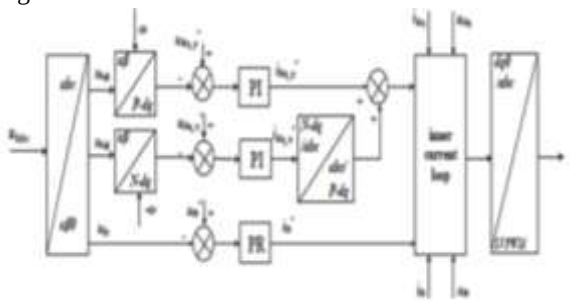

Fig.7. Diagram for constant AC voltage control

Based on the double closed-loop control mode of the inner loop of the voltage outer loop inductor current, the load voltage feed-forward is added. Double-order voltage loop and zero-axis voltage control loop output are all transformed to the positive sequence coordinating system as the current loop command. After the comparison with the feedback inductor current, it is controlled by the PI regulator and added to the load voltage feed-forward term to obtain the bridge modulation voltage of the converter. Finally, transformed to the three-phase stationary coordinate system and obtaining the drive pulse of each switch by space vector modulation. The current inner loop control structure is same as the inner current loop.

VI. CONCLUSION

Here we discussed about the problem of substation application in the AC and DC hybrid power distribution system. For adapting to the development of the more complex distribution network, a flexible substation is proposed in section. The introduced system here consists of AC high/low voltage ports and DC high/low voltage ports simultaneously. Except can achieve the voltage transformation and electrical isolation, which same with the conventional substation. What is more, it can realize the power flow control between the grid side and the load side only with its local control. In addition, in order to ensure the flexible and stable operation of the entire system, the corresponding coordination control strategy is designed.

ACKNOWLEDGMENT

Author is thankful to the supporting faculties for giving facility and opportunity while doing the work.

REFERENCES

[1] B. Olek; M. Wierzbowski., “Local Energy Balancing and Ancillary Services in Low-Voltage Networks With Distributed Generation, Energy Storage, and Active Loads,” IEEE Transactions on Industrial Electronics, 2015, 62: 2499-2508.

[2] R. Poudineh; T. Jamasb., “Distributed generation, storage, demand response and energy efficiency as alternatives to grid capacity enhancement,” Energy Policy, 2014, 67: 222-231.

[3] J. Rodríguez-Molina, J.F. Martínez, P. Castillejo., “A Study on Applicability of Distributed Energy Generation, Storage and Consumption within Small Scale Facilities,” Energies, 2016, 9: 745.

[4] R.G. Jahromi, A.R. Seifi., “The demand side management program considering AC/DC hybrid distribution system concept based on the energy hub,” Iranian Conference on Electrical Engineering, 2016: 384- 388.

[5] Y. Li, N. Chen, C. Zhao., “Research on evaluation index system of low carbon benefit in AC/DC hybrid distribution network,” In Proceedings of the International Conference on Electricity Distribution (CICED), Xi’an, China, 10-13 August 2016, 1–6.

[6] H.M.A. Ahmed, A.B. Eltantawy, M.M.A. Salama., “A Planning Approach for the Network Configuration of AC-DC Hybrid Distribution Systems,” IEEE Transactions on Smart Grid, 2016, 99: 1-10.

[7] P. Kadurek, J.F.G. Cobben, W.L. Kling., “Aiding Power system support by means of voltage control with intelligent distribution substation,”

IEEE Transactions on Smart Grid, 2014, 5: 84-91.

[8] W. Wu; X.Z. Wu; L. Jing., "Design of modular multilevel converter hardware-in-loop platform based on RT-lab," In Proceedings of the International Power Electronics and Motion Control Conference (IPEMC-ECCE Asia), Hefei, China, 22-26 May 2016, 2350-2355.

[9] J.P. Lee, B.D. Min, T.J. Kim., "Input-Series-Output-Parallel Connected DC/DC Converter for a Photovoltaic PCS with High Efficiency under a Wide Load Range," Journal of Power Electronics, 2010, 10: 9-13.

[10] J. Shi, J. Luo, X. He., "Common-Duty-Ratio Control of Input-Series Output-Parallel Connected Phase-shift Full-Bridge DC–DC Converter Modules," IEEE Transactions on Power Electronics , 2011, 26: 3318- 3329.