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2024 Paris Session

10143
B4 DC SYSTEMS & POWER ELECTRONICS
PS1 DC Equipment and System

EMT simulation of an MTDC system integrating Modular Multilevel DC/DC converter with DC voltage control

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SUMMARY

The increasing demand to utilize renewable energy necessitates the transmission of power over long distances. HVDC technology has emerged as the optimal solution for this purpose due to fewer losses and good economic factors. Multi-terminal DC (MTDC) systems are being more focused nowadays, as they offer more advantages over Point to Point (P2P) HVDC scheme because the MTDC network adds more reliability and flexibility to the system. DC/DC converters are emerging as an important device for future MTDC transmission systems. They are required to interconnect HVDC links with different system characteristics such as different DC voltage levels, grounding schemes, and technologies. In addition to this, DC/DC converters are capable of providing additional features in the system like grid protection, DC voltage control, and power flow control. The majority of studies in the literature on DC/DC converters are predominantly focused on the context of either exploring different DC/DC converter topologies or their control and operation in constant power mode for interconnecting HVDC links, suitable for future MTDC grids.
This paper presents an MTDC test case integrating a DC/DC converter where the converter is working with a DC voltage controller and participating in the DC voltage management system. The influence of voltage-controlled DC/DC converter is studied by introducing power disturbances in the MTDC system. The system is modeled and simulated in EMTP software. The droop control technique known for the VSC converter for DC voltage control is extended to obtain a dual droop controller which is used with a DC/DC converter for controlling both DC grid voltages simultaneously. However, this control approach involves designing two droop coefficients for their respective DC grids, complicating the examination of their interaction. Another possibility is to use a new technique called "virtual resistance DC voltage control" which requires tuning only one parameter. The objective is to control DC grid voltages and establish a link between the interconnected networks. The control approach is validated through electromagnetic transient (EMT) simulations. Through the virtual resistance DC voltage control, the interconnected DC grids can share the power disturbance in the system and maintain the DC voltages under their specified limits. This makes the MTDC system more reliable and reduces the stress

on the DC voltage management system. Modular multilevel converter (MMC) based topologies are used for DC/DC converters, namely F2F-MMC (front-to-front MMC) which can provide galvanic isolation between the two links and MMC-DC (M2DC) which does not provide galvanic isolation. A comparison analysis has also been made to compare their behavior with a virtual resistance controller. All converters are modeled using reduced order modeling methodology and the DC cables are modeled with wideband models.
The observations in this paper indicate that by employing the virtual resistance DC voltage controller, a connection has been established between interconnected networks, enabling HVDC links to actively participate in and share the power disturbances within the MTDC system. Apart from this, the virtual resistance control behavior remains consistent regardless of the topology of the DC/DC converter, thus demonstrating its robustness as a DC voltage controller.

KEYWORDS

DC/DC converter, DC voltage control, Front-to-Front Modular Multilevel Converter (F2F-MMC), MMC-DC (M2DC), Multi-Terminal HVDC grids

1. INTRODUCTION

The rising need for the installation of wind, solar, and hydropower plants for utilizing renewable energies requires long-distance power transfer, for which HVDC technology has been recognized as the best solution. Nowadays, Multi-terminal DC (MTDC) systems are being more focused as they have more advantages over Point to Point (P2P) HVDC scheme because the MTDC network offers more reliability and flexibility to the system [1]. Eventually, the concept of DC supergrid emerged formed by the interconnection of several MTDC networks [2]. Building a DC grid would require interconnecting already existing P2P links or MTDC networks, which cannot be done directly as each network has its own specifications. Such as HVDC links with different voltage levels or grounding configurations (bipolar, monopolar) or systems based on different technologies i.e., Line Commutated Converter (LCC) or Voltage Source Converter (VSC), would require a mandatory intermediate component in order to interconnect them. Thus, to adapt to these differences DC/DC converters are necessary as an intermediate component and play a crucial role in the development of future DC grids [3], [4].

Most studies in the literature on DC/DC converters are focused in the context of exploring different topologies and their control, suitable for future MTDC grids [5], [6], [7], [8]. Some studies present in the literature validate the operation and application scenarios of integrating DC/DC converters in MTDC grids for interconnecting different HVDC networks in normal and faulty conditions, i.e., interconnecting LCC and VSC-based HVDC links or networks with different grounding scheme [4], [9], [10], [11]. But, in these studies, DC/DC converters are considered in constant power mode and are used only for maintaining a power flow in the system, decoupling the interconnected HVDC networks. A major aspect of a stable HVDC system is providing robust and efficient DC voltage management. Through DC/DC converters working in voltage control mode, there is a possibility to share the power disturbance occurred among the interconnected grid in the meshed MTDC system and help in DC voltage management. Thereby, increasing the reliability of the whole system and reducing the stress on DC voltage management. Few studies focus on the advantage of DC/DC converter working in voltage control mode [12], [13]. However, they utilize the master-slave or voltage droop control [14] technique linked to VSCs, which could control the DC voltage of one side of the interconnected DC grids. Thus, no concrete studies or controllers are associated with DC/DC converters working in DC voltage control.

In this paper, an electro-magnetic transient (EMT) simulation of an MTDC system has been carried out to study the behavior of DC/DC converters in voltage control mode. Possible voltage controller techniques are explored link to the DC/DC converter in order to provide support in the DC voltage management. A dual droop DC voltage controller is presented to control the two DC voltages of the connected grid through a DC/DC converter. But, this control requires tuning two droop coefficient parameters related to their respective DC grid so the interaction between them is complex to study. Therefore, a voltage controller known as the virtual resistance DC voltage controller technique is used, inspired by the voltage droop controller known for VSCs and this controller requires to design of only one resistance droop coefficient. The main objective is to control the two DC grid voltages at the same time and to establish a link between the interconnected grids. Thereby, inducing the functionality to participate in sharing the power disturbance between the interconnected grids and making the system more reliable.

DC/DC converters are majorly classified based on the property of providing galvanic isolation [15]. The choice of topology depends on the MTDC system characteristics, as different topology has different advantages. The two most attractive topologies from each family based on modular multilevel converter (MMC) structure are F2F-MMC (front to front MMC) [16], [17] with galvanic isolation and MMC-DC (M2DC) [18], [19] without galvanic isolation property. Thus, F2F-MMC and M2DC converters are considered in this study representing topologies from each family of DC/DC converter.

In section II, the paper presents DC voltage control techniques associated with DC/DC converters. Section III briefly presents the modeling and control of different components of the studied MTDC system. Section IV illustrates the behavior of DC/DC converters in voltage control mode through EMT simulations. Also, a comparative study has been made between F2F-MMC and M2DC in voltage control mode with a virtual resistance DC voltage controller.

2. DC/DC CONVERTER IN VOLTAGE CONTROL MODE

2.1. Representation of case study system

The studied MTDC system configuration is presented in Fig 1. It consists of two DC links interconnected with a DC/DC converter. Each DC grid is a P2P link based on MMC HVDC technology and have a symmetrical monopole grounding configuration. The AC grids are modelled with an ideal voltage source with a series impedance. DC grid 1 is a $\pm 400kV$ network with a cable length of $200km$, where MMC11 is in voltage droop control mode with droop coefficient k_{dr1} and MMC12 in power control mode. Similarly, DC grid 2 is a $\pm 320kV$ network with two stations MMC21 (voltage droop control mode with droop coefficient k_{dr2}) and MMC22 (power control mode) connected through a cable of $300km$ length. The two DC grids with different DC voltage levels are interconnected through DC/DC converter. The DC/DC converter is installed at $25km$ distance from both DC grids at the middle point of their respective DC cables.

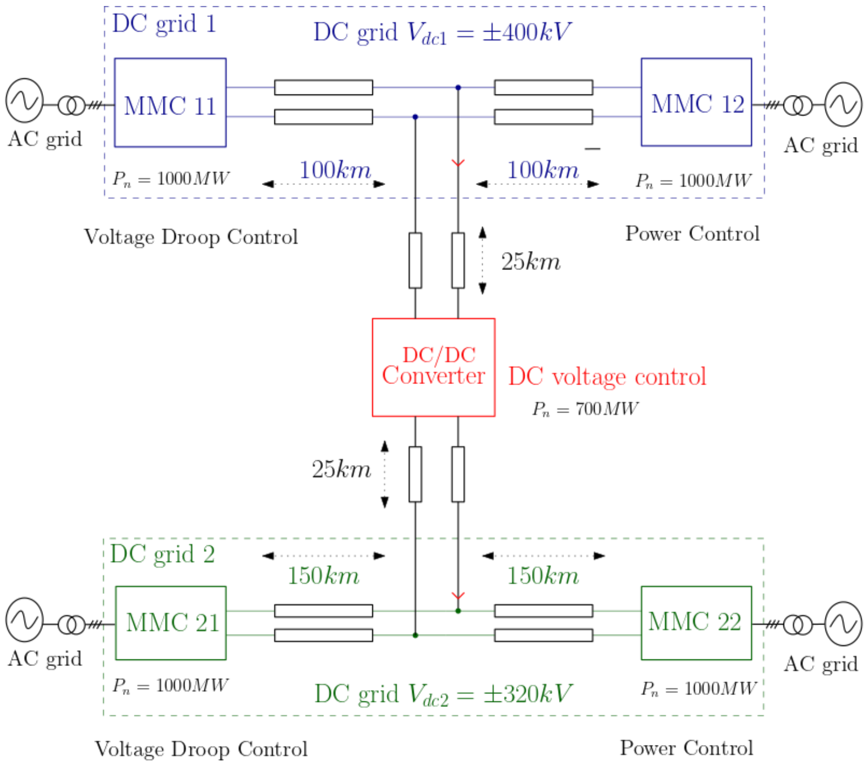


Figure 1: MTDC test case system layout

2.2. DC voltage controller for DC/DC Converter in HVDC Grid

As stated before, DC/DC converter could be used for additional functionalities in addition to the constant power exchange between the interconnected links in a MTDC system. The purpose of DC/DC converter to work in DC voltage control mode is to participate in DC voltage management of the DC system. It establishes a link between the interconnected networks, so that both networks could support each other in case of any disturbances. For instance, DC/DC converter reference power $P_{ref}^{dc/dc}$ is given by equation (1), where $P_o^{dc/dc}$ is the constant power, given by the TSO set-point for instance, and $\Delta P^{dc/dc}$ is the additional power for providing DC voltage support associated to DC voltage controller of DC/DC converter.

$$P_{ref}^{dc/dc} = P_o^{dc/dc} + \Delta P^{dc/dc} \tag{1}$$

The most widely known controller for VSC's are master slave and DC voltage droop control. Using these controllers for DC/DC converter could help in supporting DC voltage but only one of the either side of the DC voltage at a time. Thus, in this section, DC voltage controller methods are discussed in order to support both DC voltages of the interconnected networks simultaneously.

Dual droop DC voltage controller

In order to provide the support for both DC grid voltage by DC/DC converter, we could employ dual droop control (i.e., two droop control each for one MTDC grid voltage). The DC voltage dual droop controller presented is inspired by the dual droop control for controlling AC grid frequency and DC grid voltage at the same time [20]. The schematic is given in Fig 2. where, the variables V_{dc1}, V_{dc2} and $V_{dc1\,ref}$, $V_{dc2\,ref}$ are the measured and nominal (reference) DC grid voltages respectively and k_{dual1}, k_{dual2} are the dual droop coefficients. With dual droop control, we have the possibility of controlling both DC grid voltage at the same time with different droop coefficients. However, with dual droop control, we require to tune two droop coefficients related with each independent HVDC network. Also, in a meshed MTDC system, the design of dual droop coefficients could be complex due to the interactions between different controllers.

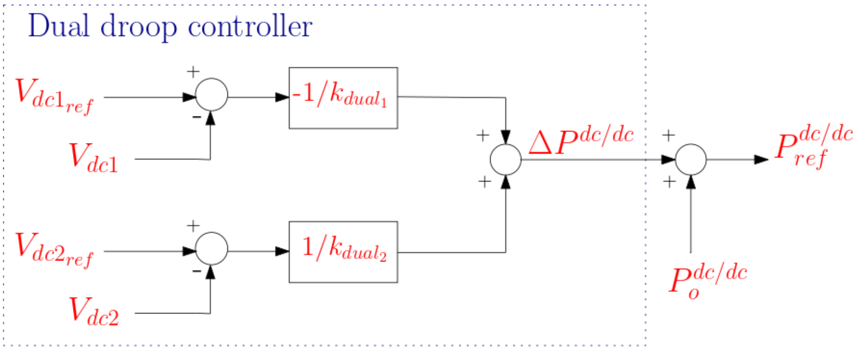


Figure 2: Dual droop DC voltage controller

2.3. Virtual resistance DC voltage controller

To overcome the limitation of dual droop controller, a controller called "virtual resistance DC voltage controller" has been proposed which requires to design only one coefficient. It is based on the idea of DC/DC converter acting as a virtual resistance and establishing a link between the interconnected HVDC networks to support each other. The virtual resistance controller is inspired by the DC voltage droop control methodology. The control structure is presented in Fig 3., and the relation is illustrated by equation (2), where ntr is the rated DC voltage ratio ($V_{dc2\,ref}/V_{dc1\,ref}$) and R_{dr} is the resistance droop coefficient.

$\Delta I^{dc/dc}$ is the compensating current reference which is generated by the action of virtual resistance control if the DC voltages deviate from their rated value due to any disturbance in the MTDC system. The corresponding compensating power $\Delta P^{dc/dc}$ is generated in order to balance the power among MTDC grids and it depends on the deviated DC voltages difference and resistance droop coefficient as shown in equation (3). Thus, with the help of virtual resistance controller, a coupling is established between the interconnected networks and DC/DC converter could participate in DC voltage management, supporting both DC grid voltage simultaneously. Therefore, the stress on the DC voltage management system is reduced and the reliability of the system is increased.

$$\Delta I^{dc/dc} = \left(-\frac{1}{R_{dr}}\right)(V_{dc2} - ntr\ V_{dc1}) \tag{2}$$

$$\Delta P^{dc/dc} = \left(-\frac{1}{R_{dr}}\right)(V_{dc2}^2 - ntr\ V_{dc1}\ V_{dc2}) \tag{3}$$

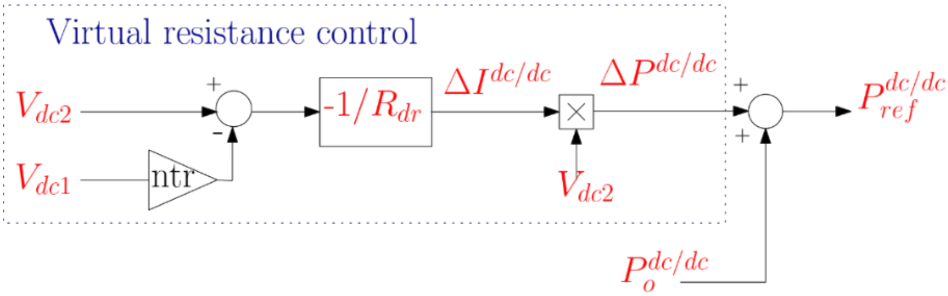


Figure 3: Virtual Resistance DC voltage controller

Designing of resistance droop coefficient R_{dr}

The resistance droop coefficient is designed using the relation obtained by equation (3) and applying the steady state constraints on the power variation $\Delta P^{dc/dc}$ and the maximum deviation of the DC grids voltages V_{dc1} and V_{dc2}. DC/DC converter is limited by its rated power, so the constraint on $\Delta P^{dc/dc}$ depends on the rated power of DC/DC converter ($P_{rated}^{dc/dc}$) and the power $P_o^{dc/dc}$ as shown in equation (4). The constraints are applied on the DC voltages to keep them under their acceptable limit which is usually ±5%. In addition to this, there are individual local DC voltage controller at both DC grid, and so the constraint on the deviation of V_{dc1} and V_{dc2} also depends on their respective DC voltage controller methodology.

Considering two worst case scenarios where, in case1 the DC voltage droop controller is present only at DC grid 1 at station MMC11. When the power disturbance will occur on the MTDC system, the voltage deviation of V_{dc1} is determined by relation of voltage droop control of MMC11 as shown in equation (5a). Whereas, the voltage deviation of V_{dc2} is put on the constraint of ±5% limit. In case2, the DC voltage droop controller is considered to be present only at DC grid 2 at station MMC21. Similar to the previous case, the voltage deviation of V_{dc2} is determined by relation of voltage droop control of MMC21 as shown in equation (5b) and voltage deviation of V_{dc1} is under the constraint of ±5% limit.

$$\Delta P^{dc/dc} = \pm P_{rated}^{dc/dc} - P_o^{dc/dc} \tag{4}$$

$$Case1: \qquad V_{dc1} = V_{dc1\,ref} - (-k_{dr1}\,\Delta P^{dc/dc}) \tag{5a}$$

$$Case2: \qquad V_{dc2} = V_{dc2\,ref} - (-k_{dr2}\,\Delta P^{dc/dc}) \tag{5b}$$

$$R_{dr} = \left| \frac{(V_{dc2}^2 - ntr\,V_{dc1}\,V_{dc2})}{\Delta P^{dc/dc}} \right| \tag{6}$$

Following the above constraints and rewriting equation (3), R_{dr} is calculated using relation (6). In order to satisfy all the constraints simultaneously, the best suitable value of R_{dr} for a given MTDC system is the minimum value obtained in the calculation. The value of R_{dr} has to be updated following a change in the system specification as its value depends on the operating point of DC/DC converter and system parameters (k_{dr1}, k_{dr2}).

3. MODELLING AND CONTROL OF SYSTEM COMPONENTS

In this section, a brief discussion is presented on the modelling and control of AC/DC and DC/DC converters in the MTDC case study system. The DC/DC converter topologies studied in this paper are F2F-MMC and M2DC as shown in Fig 4. Reduce order model (ROM) methodology [21] is adopted to model all the converters of the system as discussed below. The DC cables are modelled using the most accurate wide-band model [22] in EMTP.

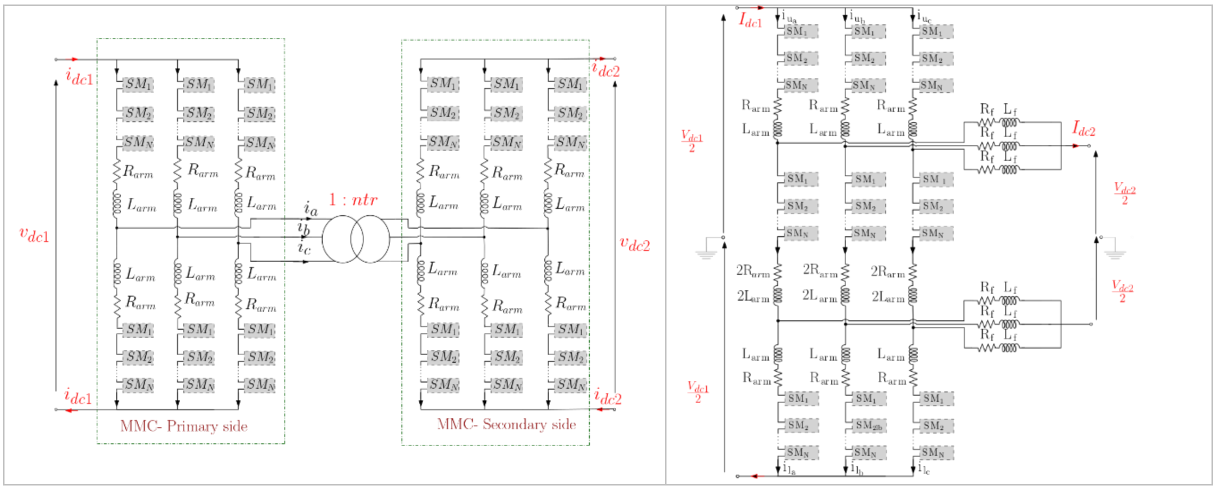


Figure 4: F2F-MMC converter (left side), M2DC converter (right side)

MMC converter

ROM methodology presented in Fig 5. [21] is used to model MMC converters. They are derived from average-arm model following the assumptions that there are no circulating currents in the arms and the internal energy of the sub-modules (SMs) capacitor are balanced. The classical control scheme is adopted based on the inversion base rule. The inner loops consist of AC and DC current controllers which are decoupled form each other. The reference for DC current is given by the outer energy control loop which controls the total energy stored in the equivalent capacitor of the converter. The AC current reference is depending on the power reference which further depends on the MMC control mode, i.e., controlling the DC voltage or the AC power of the converter.

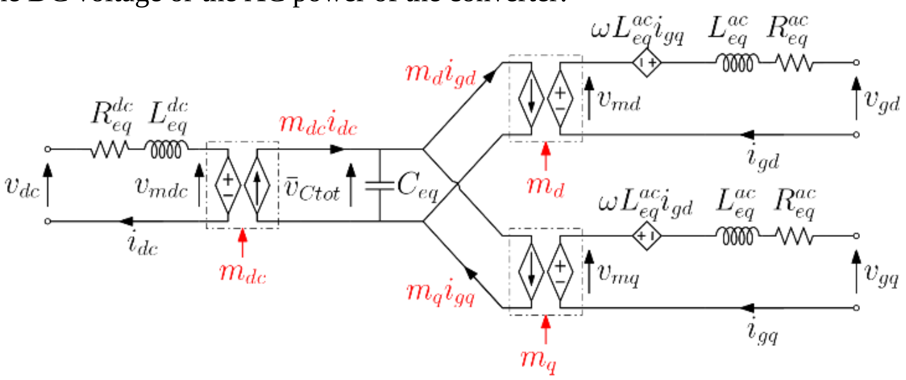


Figure 5: MMC Reduced Order Model (Left side), MMC ROM Control Scheme (Right side)

F2F-MMC converter

The ROM model of F2F-MMC is deduced by cascading two ROM model of MMC, front to front with a transformer on AC side. The DC currents and the energy stored in the equivalent capacitor of both sides MMC are controlled independently as discussed above. Whereas, to control the AC current we adopt the control scheme presented in [16], where one MMC of the F2F-MMC fixes its AC voltage and the other MMC is responsible for controlling the AC current.

M2DC converter

The ROM of M2DC converter is derived following the same approximation as with MMC. Complete derivation is presented in [23] and the structure is shown in Fig 6. The two DC grids of M2DC has a direct coupling between them as the current flowing in the secondary DC grid has a direct impact on the

DC side1 current. The internal equivalent capacitor is linking both sides of M2DC converter. The control structure consists of controlling both DC current independently. The reference of DC current 1 is given by the stored energy control of equivalent capacitor and the reference of DC current2 is provided by the power reference coming form the DC voltage controller of M2DC (virtual resistance or dual droop controller).

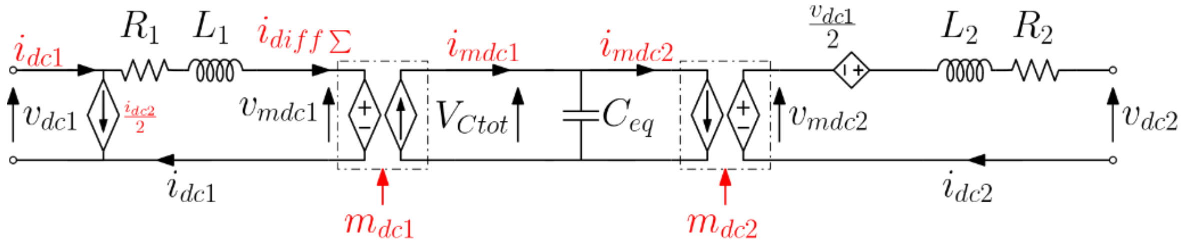


Figure 6: Reduce Order Model of M2DC converter

4. DYNAMIC BEHAVIOR IN CASE OF EVENTS

In this section, the behavior of DC/DC converter in DC voltage control mode is presented through EMT simulation using EMTP software. The MTDC test system considered is presented in Figure 1 and the converter and control parameters are shown in Table I and Table II. M2DC converter topology is adopted for DC/DC converter as the interconnecting links has a small voltage ratio ($V_{dc1}/V_{dc2} \leq 1.5$) and so it might not require the galvanic isolation between the two links [4].

TABLE I
Converters Parameters

Parameter	MMC11, MMC12	MMC21, MMC22	M2DC	F2F-MMC
DC voltage	$800\ kV$	$640\ kV$	$\pm 400\ kV / \pm 320 kV$	$800\ kV / 640 kV$
Rated power	$\pm 1\ GW$	$\pm 1\ GW$	$\pm 700\ MW$	$\pm 700\ MW$
Frequency	$50\ Hz$	$50\ Hz$	$150\ Hz$	$150\ Hz$
Arm inductance	$50\ mH$	$50\ mH$	$11.42\ mH$	$50\ mH$
AC output inductance	$50\ mH$	$60\ mH$	$114\ mH$	$60\ mH$
Equivalent SM arm capacitance	$15.6\mu F$	$32.5\mu F$	Upper & Lower arm: $90\mu F$ Middle arm: $162\mu F$	Primary side: $16\mu F$ Secondary side: $32\mu F$

TABLE II
Control Parameters

Parameter	Value
DC/DC virtual resistance coefficient R_{dr}	$3.4605\ \Omega$
DC/DC dual droop coefficients (k_{dual1}, k_{dual2})	$0.05\ p.u.$
MMC voltage droop coefficients (k_{dr1}, k_{dr2})	$0.05\ p.u.$
Current controller (damping ratio, time constant)	$0.7, 1ms$
Energy controller (damping ratio, time constant)	$0.7, 50ms$

4.1. Influence of virtual resistance controller with M2DC converter in an MTDC system

M2DC converter is working with virtual resistance DC voltage control. Resistance droop coefficient is calculated following the design and constraints as discussed in section 2. The power $P_o^{dc/dc}$ of DC/DC converter is $150M$ flowing from DC grid1 to DC grid2. In order to observe the influence of virtual resistance controller, different power disturbances are introduced at different time intervals in the MTDC system. In the presented waveforms, the DC power flowing into an MMC station is represented with a positive sign whereas the power coming from the MMC station is represented with a negative sign.

Case1: In the first case, at $t = 1sec$, a power disturbance is introduced at DC grid1. The power demand at MMC12 station is decreased by $100MW$. The resulting DC voltage and DC power waveform at all stations are shown in Fig 7. As, the power at MMC12 station is decreased, so the DC voltage at DC grid1 starts to increase. This activates the DC voltage controllers present in the system. As observed from Fig 7., the power at DC voltage-controlled station MMC11 (dotted blue curve) as well as at station MMC22 (dotted red curve) from DC grid2 is changed in order to compensate the power disturbance at DC grid1. Thus, due to the coupling formed by virtual resistance control, the power disturbance at DC grid1 is shared by both DC grids. The DC grid voltages at all stations are maintained under the 5% limits.

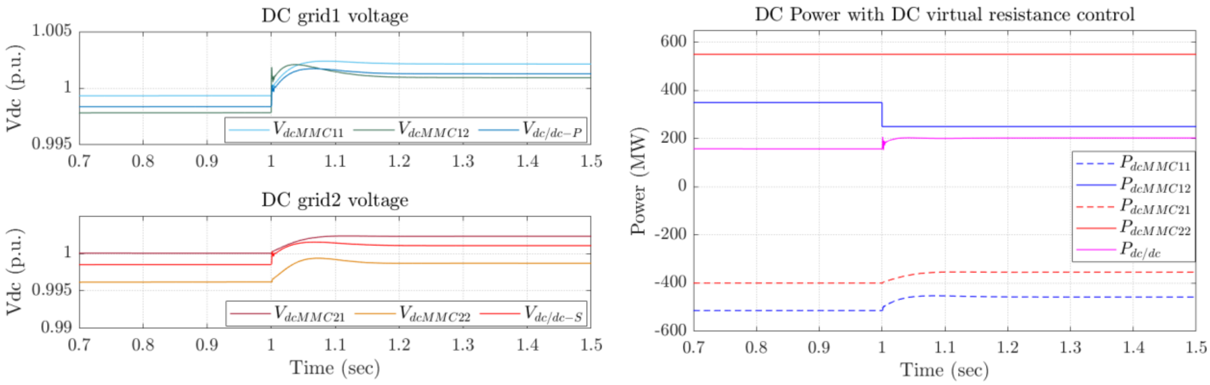


Figure 7: Case1: Power disturbance at station MMC12 (DC grid 1)

Case2: In the second case, at $t = 1.5sec$, the power demand at MMC22 is increased by $150MW$. This introduces a power disturbance at DC grid 2. The resulting waveforms are presented in Fig. Similar to case1, as can be observed from Fig 8. the power imbalance at DC grid2 is compensated by station MMC21 (DC grid 2) as well as station MMC11 at DC grid1. Thus, through virtual resistance controller, a link between both DC grids has been established. Sharing of the power disturbance among the interconnected DC grid has been validated along with maintaining DC voltages under specified limits.

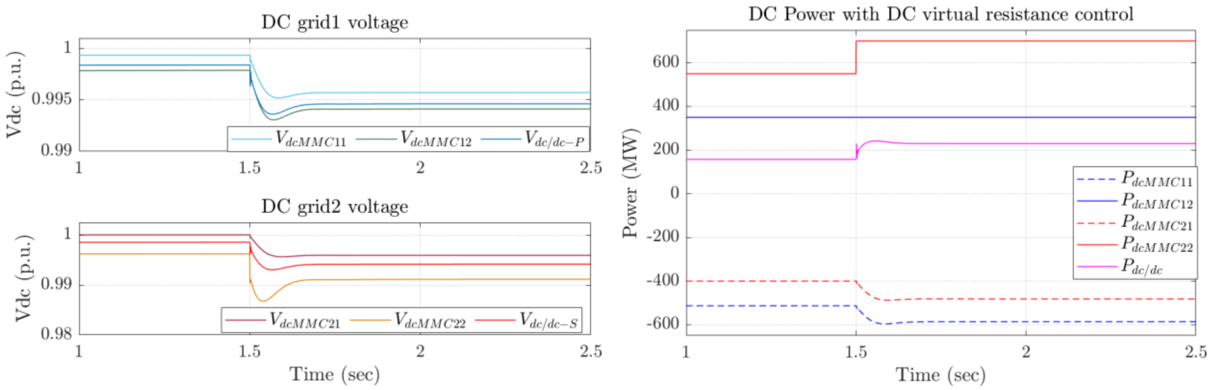
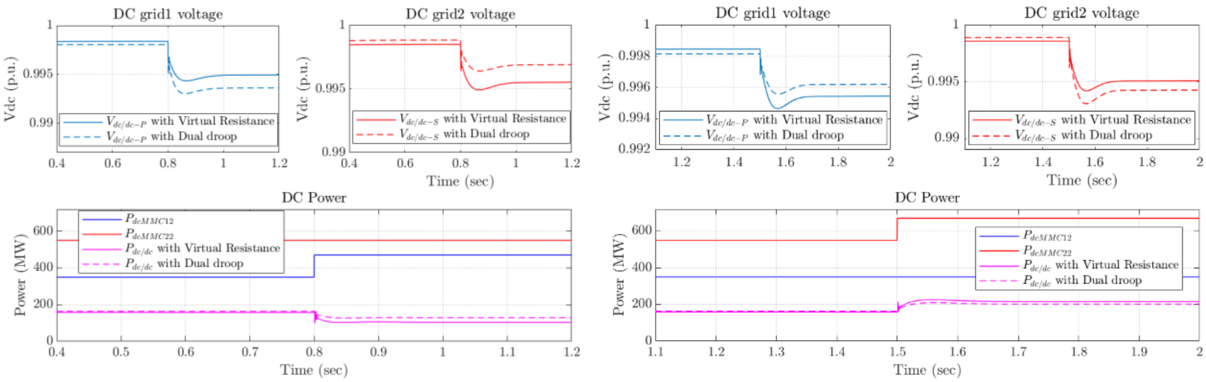


Figure 8: Case2: Power disturbance at station MMC22 (DC grid 2)

4.2. Dynamic behavior comparison between Virtual resistance and Dual droop controller

In this section the dynamic behavior of MTDC system integrating M2DC converter with dual droop DC voltage control is studied and the results are compared with virtual resistance DC voltage controller. The droop coefficients for dual droop voltage control of M2DC converter is chosen as $0.05 p.u.$, i.e., the same design as the voltage droop coefficient of their respective DC grid voltage controller MMC station. Power disturbances are introduced in both DC grids and the behavior of DC voltage and power are observed as shown in Fig. 9. In one case, at $t = 0.8sec$, the power demand at station MMC12 at DC grid1 is increased by $120MW$ and the results are shown in Fig. 9 (a). In the second case, at $t = 1.5sec$, power demand is increased by $120MW$ at station MMC21 at DC grid2 and the results are presented in Fig. 9 (b). These events introduce a power imbalance in the MTDC system. Thus, for both the two events, the power disturbance is shared and compensated by both voltage-controlled station MMC11 (DC grid1) and MMC21 (DC grid2). For simplicity, only the results of DC voltage and DC power at M2DC converter station are presented.

As we can observe from Fig. 9, the resulting waveforms have similar dynamic behavior with dual droop control and virtual resistance control. Also, the DC voltages are in the 5% limits with both controllers. There is a difference in steady state values and static behavior due to the difference in droop coefficients values of the controllers. Thus, the virtual resistance controller has similar dynamic characteristics as dual droop controller. But with dual droop controller we need to optimize two droop coefficients whereas the virtual resistance controller requires to tune only one droop coefficient. Therefore, for M2DC converter, the virtual resistance DC voltage controller is simpler to implement.



(a) (b)

Figure 9: Comparative results between Virtual resistance and Dual droop controller. (a) Disturbance in DC grid1. (b) Disturbance in DC grid2.

4.3. Comparison between F2F-MMC and M2DC converter with virtual resistance DC voltage controller

In the previous parts, M2DC converter topology was used for DC/DC converter. Now, the influence of virtual resistance DC voltage controller is studied integrated with F2F-MMC DC/DC converter topology, and the results are compared with the case of M2DC topology. Power disturbances are introduced in the MTDC system same as section 4.2, by increasing the power demand ($120MW$) at MMC12 (DC grid1) and MMC22 (DC grid2) station at $t = 0.8sec$ and $t = 1.5sec$ sec respectively. The comparative results of F2F-MMC and M2DC are presented in Fig. 10. Resulting DC voltage and powers waveforms at all stations of the system using F2F-MMC topology follows the same behavior with the results using M2DC topology. Thus, it can be concluded that virtual resistance DC voltage controller is independent of the DC/DC converter topology and can be used with all modular DC/DC converters.

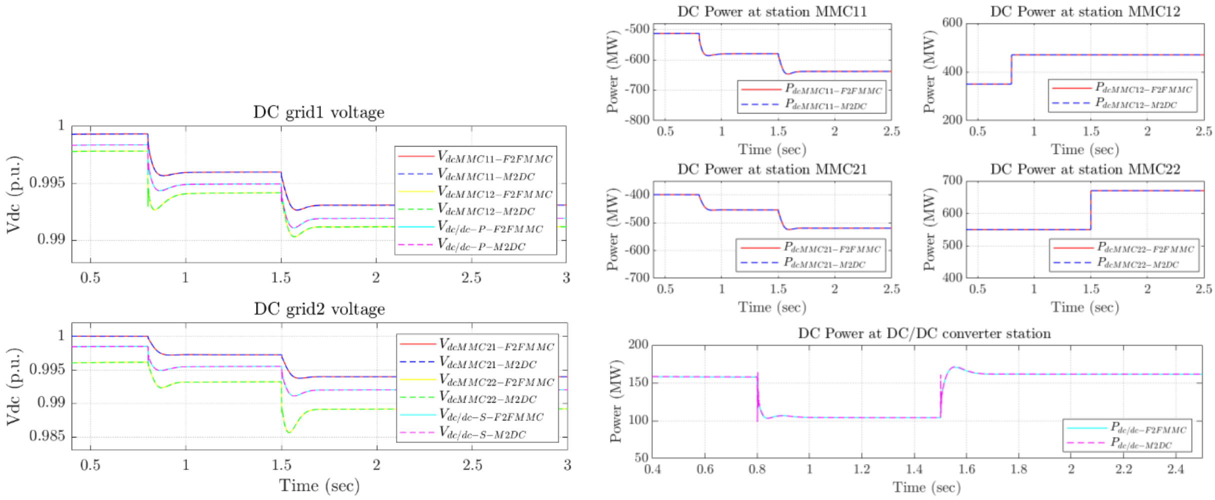


Figure 10: Comparative results between F2F-MMC and M2DC with virtual resistance control

Worst case scenario:

In this part, we observe the behavior of the system, considering the DC voltage droop controller to be present only at DC grid 1 at station MMC11. While MMC21 station working in constant power mode similar to stations MMC12 and MMC22. It is considered as a worst-case scenario as MMC21 is in constant power mode and not in DC voltage controller mode. So, any power disturbances occurring in DC grid2, cannot be compensated, and as a result, the DC voltage would increase or decrease from its rated value.

At $t = 1.2sec$, power at station MMC22 is decreased by $250MW$, introducing a power imbalance in the system. The resulting DC voltage and power waveforms with F2F-MMC and M2DC converter is presented in Fig. 11. There is no voltage-controlled station present at DC grid2 to compensate the power disturbance, so, the DC grid2 voltage starts to increase. But, DC grid2 and DC grid1 are linked with DC/DC converter through virtual resistance DC voltage controller. Thus, by the action of virtual resistance DC voltage controller, the power disturbance at DC grid2 is compensated by voltage-controlled station MMC11 present at DC grid1. As observed from Fig 11., following a small transient, DC power of the MTDC system is balanced and the DC voltages are under their limit values of 5% with both M2DC and F2F-MMC converter. Also, the DC power of DC/DC converter station is now flowing from DC grid2 to DC grid1. In this case, if the DC/DC converter operating without virtual resistance DC voltage controller would have an adverse effect at DC grid 2 due to the continuous increase of DC grid 2 voltage. Thus, thanks to virtual resistance control, in such cases, sharing the power disturbances is beneficial and increases the reliability of the MTDC system.

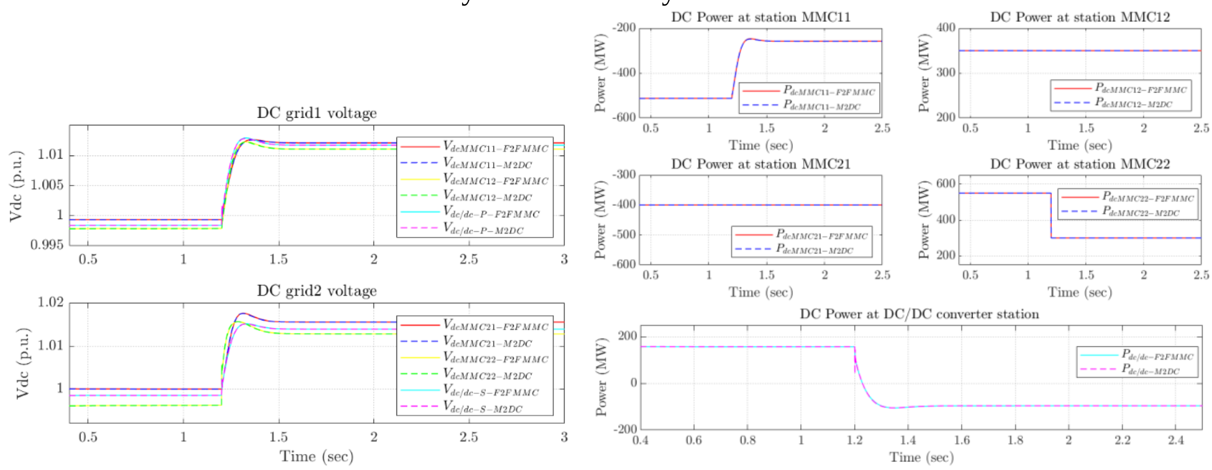


Figure 11: Variation of DC power and DC grid voltages for worst case scenario

The results presented in this section shows the working of DC/DC converter in DC voltage control mode. The interconnected HVDC links are able to share the power imbalance of the MTDC system through virtual resistance control. Thereby, increasing the reliability of the system. Working of virtual resistance controller has been validated with different case scenarios. It has been observed that virtual resistance controller has the similar dynamic behavior as dual droop controller but is easier to implement. Also, the virtual resistance control is independent to the DC/DC converter topology.

5. CONCLUSION

DC/DC converter plays an important role in the interconnection of HVDC links with different characteristics for building MTDC networks. DC/DC converter working in voltage control mode provides additional functionalities that increases the reliability of the system and help in the DC voltage management. A MTDC case study was modelled and simulated in EMTP where DC/DC converter is integrated with DC voltage controller. Power disturbances have been introduced in the system in order to study the behavior of voltage-controlled DC/DC converter. Dual droop and virtual resistance DC voltage control techniques have been presented associated to DC/DC converter. Similar dynamic response had been observed with both controllers. But the advantage of virtual resistance controller is that it requires to tune only one parameter to design the controller and thus the controller is simpler to implement. It has been illustrated that through the virtual resistance DC voltage controller, a coupling has been established between interconnected networks. Due to which the HVDC links are able to participate and share the power disturbance in the MTDC system. Also, the working of F2F-MMC and M2DC has been compared in voltage control mode. It has been observed that the virtual resistance controller behavior is independent to the topology of the DC/DC converter, thus making it a robust DC voltage controller.

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