

# **“A Novel Power Router with General AC and DC Port”**

## **ABSTRACT**

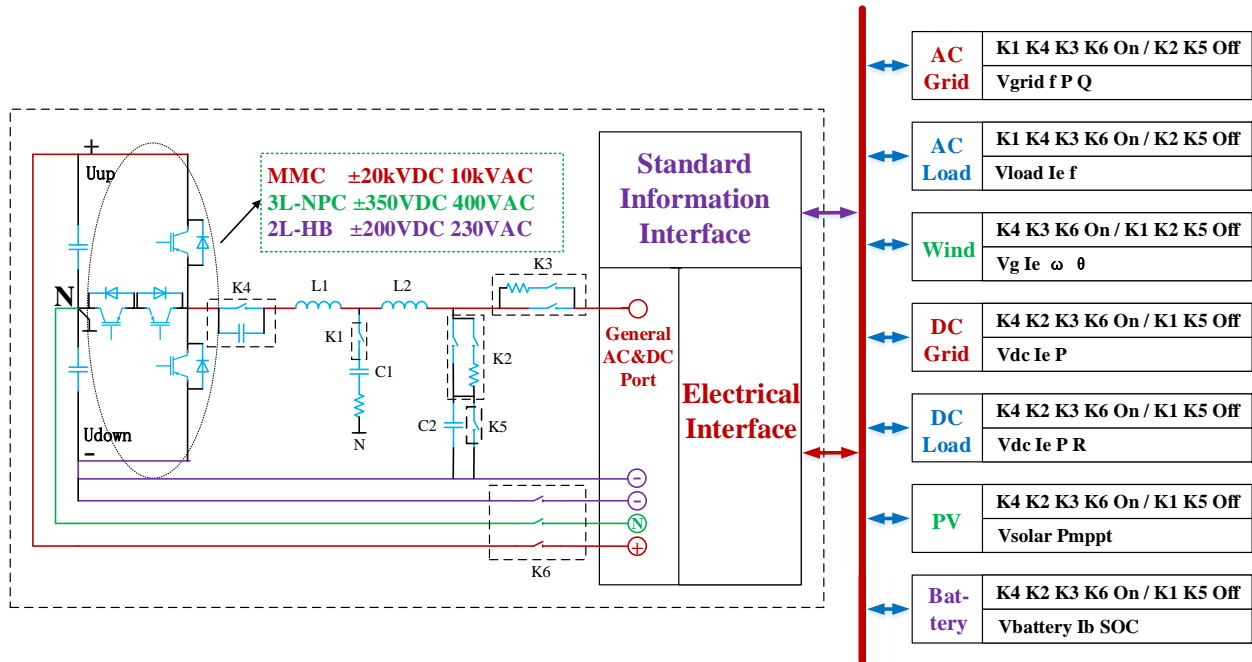
To better implement the interconnections among micro-grids, renewable energy and traditional grid, a novel power router topology is proposed in this paper. It enjoys the advantages of bidirectional power flow, plug-and-play and a general AC and DC port. The power router consists of a converter, a filter and a standard information interface. The converter's topology has various choices according to the power level of the system. The output filter switches between LC filter and LCL filter according to the converter's operation mode. The standard information interface grants the power router the ability of plug-and-play. To realize fast switching between different operating modes, the output filter is designed to shorten the transient state. Simulation results are presented in this paper to prove the effectiveness and feasibility of the proposed power router topology.

## **I. INTRODUCTION**

In recent years, the idea of smart grid, which features renewable energy resources and intelligent energy management, has been very popular. Power router (PR) is the device used in the smart grid to achieve the target of economic power management and distribution [1]. Currently, most of the proposed power routers' topology are based on dual half-bridge and high frequency transformer (HFT) [2,3]. L. Ren proposed a power router topology based on conventional three-phase inverter and DC-DC converters and pointed out the problem that HFT structure is so complicated and expensive that it is difficult to be used by manufacturing [4]. The current power router topologies have realized the routing of information and energy. However, they cannot achieve the route of ports, which means a DC port can only be used for DC applications and it is the same for AC ports. Therefore, there will be idle ports if the load or generator type doesn't meet the port requirement, which will decrease the economic efficiency. To address this problem, a novel power router topology is proposed in this paper. It enjoys the advantages of bidirectional power flow, plug-and-play and a general AC and DC port. Besides, it is not using the HFT structure. The output filter is designed to achieve fast switching between AC and DC state [5]. Simulation results are presented to prove the feasibility of the proposed power router topology.

## **II. TOPOLOGY AND THE OPERATION MODE**

As shown in Fig.1, the novel power router in single-phase contains an information interface and an electrical part, including a converter and a filter. The DC side of the converter is connected to the DC micro grid to realize bi-directional power flow between the grid and other equipment. In addition, it has many applications such as AC grid, wind energy, solar energy and batteries. Three single-phase power routers can parallel to form a three-phase structure.



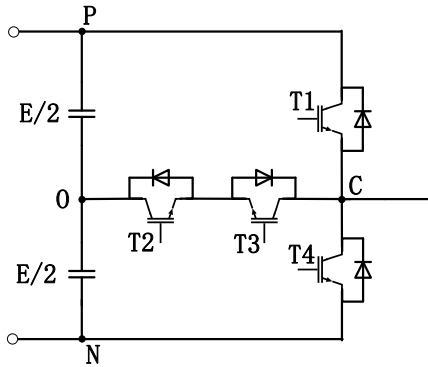
**Figure 1: Topology & Application of Novel Power Router**

It enjoys the following advantages: First, the converter topology has many choices referring to the rated power of the system and has the feature of bidirectional power flow. Second, the novel power router has an information interface, which enables it to realize plug-and-play through ways of control. Third, it has a general AC and DC port. Thus, various types of energy such as solar and wind can be connected to the power router through the same port.

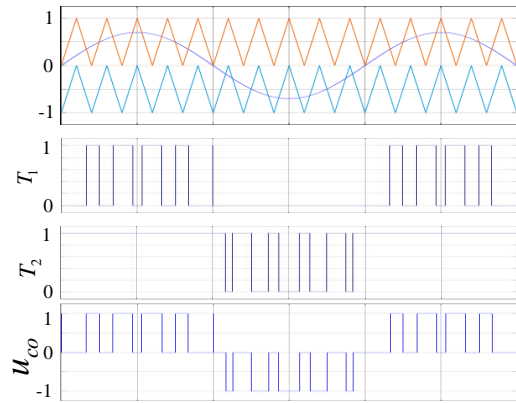
When the power router operates in AC mode, the switch state is chosen according to the type of equipment that is connected. In the first case, AC grid or AC loads are connected, K1, K3, K6 are on and K2, K5 are off. K4 is used for soft start and after that, it is off. The output forms a LCL filter. Another case is that permanent magnetic synchronous machine (PMSM) used for wind turbine is connected, K3, K4, K6 are on and K1, K2, K5 are off. The output forms a L filter, transferring power through the power router.

When the power router operates in DC mode, K2, K4, K6 are on and K1, K5 are off. K3 is used for soft start and after that, it is off. The output forms a LC filter. In this mode, DC grid, DC loads, Photovoltaic (PV) Panels and batteries can be connected.

### III. MODULATION and CONTROL

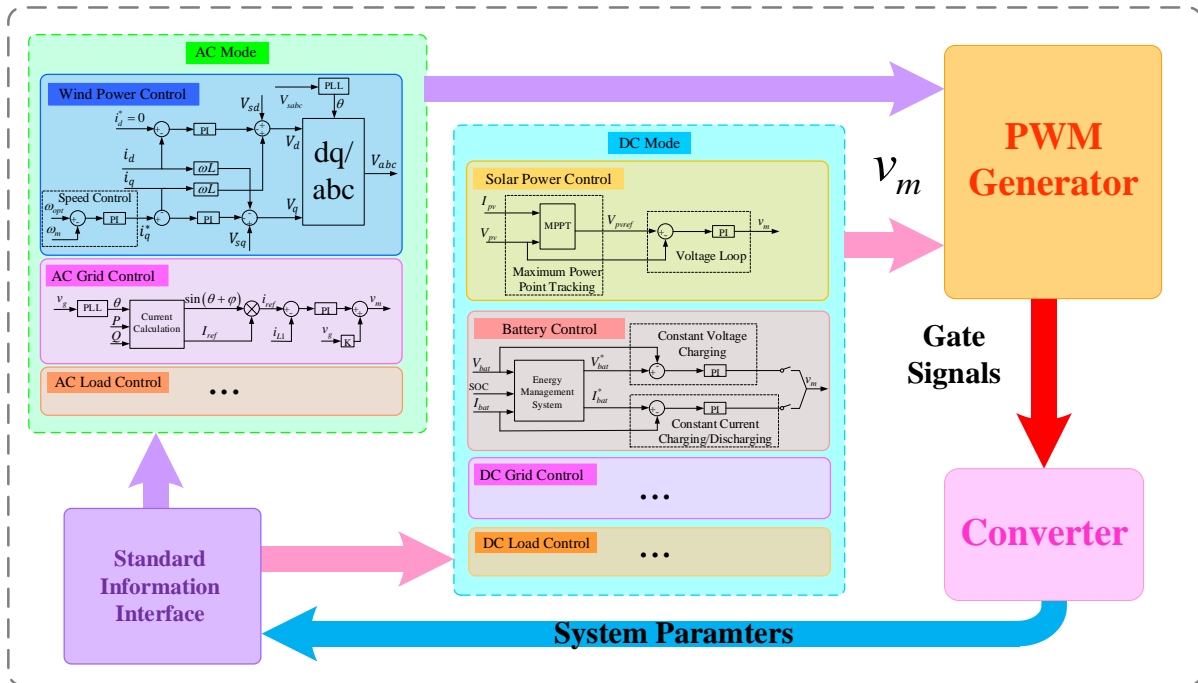


**Figure 2: T-type three-level converter topology**



**Figure 3: Phase-Disposition PWM**

As shown in Figure 2, the simulation and analysis presented in this paper is based on the T-type single-phase three-level converter topology, which is normally used in medium power applications. Figure 3 indicates the modulation of a T-type three level converter. When converter operates in AC mode, phase-disposition PWM (PD-PWM) is applied. The gate signals of T1 and T3 also T2 and T4 are complementary. In figure 3, the orange signal is the carrier wave of T1 and T3, while the blue signal is the carrier wave of T2 and T4. The purple signal is the modulation wave. Then, the gate signals of T1 and T2 show that the output voltage will be a three-level waveform.



**Figure 4: Control Scheme of the Novel Power Router**

When the converter operates in DC mode, to avoid midpoint potential imbalance, T2 and T3 are closed. The gate signals of T1 and T4 are complementary and the output voltage is a two-level waveform.

Figure 4 shows the control scheme of the novel power router. The Standard Information Interface first get the information of the equipment to be connected. Then, control method is chosen according to the control target. After that, the modulation wave is given to the PWM generator to generate gate signals and run the converter. For different operating modes, the modulation wave, modulation method and control methods are different. In AC mode, wind power control meets the target of Maximum Power Point Tracking (MPPT) by controlling the speed of PMSM; AC grid control meets the target of frequency, active power and reactive power control by controlling the in-grid current; AC Load control meets the target of frequency, voltage and power control by controlling the load voltage or current. In DC mode, solar power control meets the target of MPPT by controlling the PV panel voltage; battery control meets the target of energy management by constant voltage charging or constant current charging or discharging; DC grid control meets the target of active power control by controlling the in-grid current; DC load control meets the target of voltage and power by controlling the load voltage or current.

#### IV. SIMULATION

**Table 1: PR Simulation Parameters**

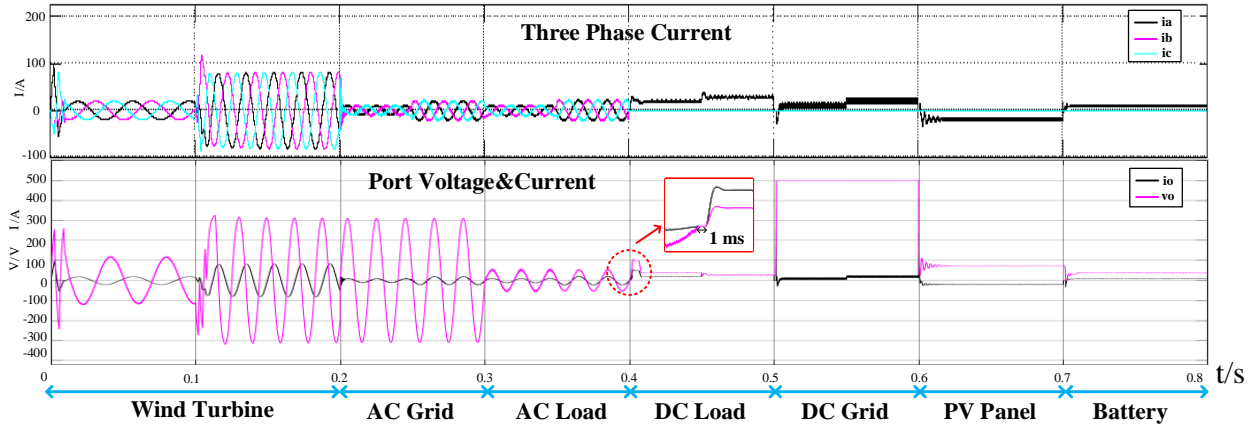
Parameters	Value
DC side voltage, $V_{dc}$	$\pm 360V$
Capacitor, $C_1/C_2$	10uF/150uF
Inductance, $L_1/L_2$	250uH/50uH
Switching Frequency, $f_s$	15kHz

Figure 5 shows the simulation result that the novel power router works under different states according to the equipment that is connected. Table 1 shows the power router parameters and Table 2 indicates the specific working states' parameters. In 0-0.2s, PMSM is connected, the power router works at AC mode. The rotor speed tracks the optimal speed

to realize MPPT. The output voltage is filtered to show a better relationship between output current and voltage. At 0.1s, there is a step in the wind speed. At 0.2s, PMSM quits and AC grid requires connecting in. In 0.2-0.3s, the power router transfers power between DC micro grid and AC grid. Power step happens at 0.25s. At 0.3s, AC grid quits and AC load is connected. In 0.3-0.4s, the power router transfers power from DC micro grid to the loads. At 0.35s, the load is cut half, so the current changes to meet constant power output. At 0.4s, AC load quits and DC load is connect in. In 0.4-0.5s, the power router works in DC mode and uses the same port to transfer power to DC load. At 0.45s, the load is cut half to check the constant power control effect. At 0.5s, DC load quits and DC grid is connected. Power step happens at 0.55s. At 0.6s, PV is connected. MPPT is realized in 0.6-0.7s. At 0.7s, PV quits

**Table 2: Simulation State Parameters**

Time/s	Equipment	Control	Wind Speed/ m/s	Load/ $\Omega$	Power/kW	Direction
0-0.1	Wind	MPPT	10		-3.6	1 Negative Power flows from equipment to DC micro grid
0.1-0.2	Turbine		20		-28.8	
0.2-0.25	AC Grid	PQ			10	
0.25-0.3					20	
0.3-0.35	AC Load	P			4.84	2 Positive Power flows from DC micro grid to equipment
0.35-0.4					2.42	
0.4-0.45	DC Load	P			2	
0.45-0.5					1	
0.5-0.55	DC Grid	P			5	
0.55-0.6					10	
0.6-0.7	PV	MPPT			-1.4	
0.7-0.8	Battery	SOC			0.4	



**Figure 5: Simulation Results of Port Current and Voltage under Different Working Conditions**

and a battery is connected. In this period, constant current control is applied according to the SOC of the battery. In the stage of AC switching to DC, fast switching is promised through the design of filter parameters. By locking the converter first, then releasing energy in inductors, unlock the converter and pre-charge for next state, the switching is safe and fast. From figure 5, it can be seen that the switching is realized in 1 ms, which is very fast. The simulation results prove the feasibility of fast switching and that the surge current or voltage is small.

## V. CONCLUSIONS and FUTURE WORK

This paper presents a novel power router topology. Compared with previous power routers, the new topology has a general AC and DC port, which means that the novel power router has the ability of port routing. This will improve the economic efficiency of the power router. Meanwhile, it can realize the bidirectional power routing and plug-and-play under information routing. Basic modulation and control method is introduced to give a better understanding of the topology. The filter is designed to give the best transient response. The design procedure will be presented in full paper. Finally, the simulation shows the feasibility of the novel topology. Future work will be done on the stability of multiple novel power routers' switching between different states.

## VI. REFERENCES

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