해저 케이블 분산 네트워크를 위한 UPQC 기반의 전압 보상 PV Source 인버터

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PV Source Inverter with Voltage Compensation based on UPQC for Submarine Cable Distribution Network

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ABSTRACT

Under voltage and over voltage are the big problems in submarine distribution system. To solve that problems, integrated PV with voltage compensation method is proposed in this paper. This paper describes a simple method for controlling the series connection converter while the shunt connection operates as a back up for sensitive load and verified by the PSIM software.

1. Introduction

Nowadays, electricity is the basic of human life needed. almost all living activities is using electricity. However not everyone can get electricity connection. The people who live in isolated area or islands face the problem to enjoy the electricity.

2. Submarine Cable Implication in Distribution Network

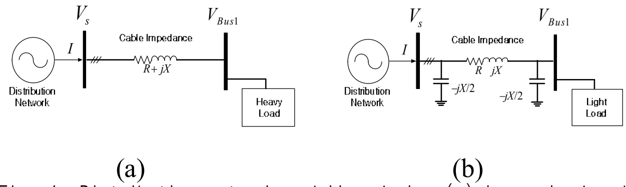
The under voltage and over voltage are faced by Island's people. An under voltage defined by IEEE 1159 is the typical voltage magnitude less than 0.9 pu for a duration longer than 1 min. In other side, over voltage is an rms increase greater than 1.1 pu for more than 1 min.

The voltage in submarine cable is affected by the loads. In heavy loads condition, under voltage can be occurred in bus 1. It can be shown from equation 1, where Vbus 1 can be reduced due to cable impedance and loads.

In other side, over voltage can be occurred also. Submarine cable has more capacitance than line. The effect of the capacitance in the medium length submarine cable is Ferranti effect which can be occurred during the light load.

$$V_s - V_{Bus1} = \frac{RP+XQ}{V_s} \quad (1)$$

$$V_s - V_{Bus1} = -\frac{V_r \omega^2 LC}{2} \quad (2)$$



(a) (b)
Fig. 1. Distribution network modeling during (a) heavy load and (b) light load.

Sensitive loads such as medical equipment, semiconductor manufacturer, and other manufacturers using automations have problem with the voltage quality. Consequently, that loads demand for the high voltage quality related to the voltage stability. One way to solve that problem is tap changer. The total range of regulation and the size of the individual step is most often specified ±10% in 32 steps of 5/8% as per IEEE std C57.131 2012. However, transformer can cover in the range of ±10% rated voltage only. Therefore, it is a challenge how to maintain the power quality within the acceptance limit based on standard [1 3].

3. Dynamics Voltage Restores As a Voltage Compensation Method

The Dynamic Voltage Restores (DVR) has been used to mitigate the under voltage on the sensitive load. The concept using DVR as voltage mitigation has given positive reaction and popularity since its first use. Several of DVR based on control strategies have also been developed in many literatures [4]. In [5], it was mentioned that the power rating of components for DVR is lower than that for D STATCOM, SVC and PFC for same level of voltage compensation.

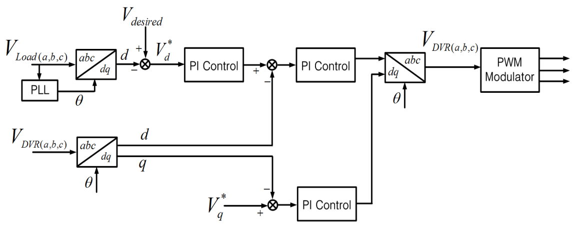


Fig. 2. Proposed control schemes for the series inverter.

The proposed PV inverter system in this paper is integrated DVR system to mitigate the voltage sag and swell at grid side. Power generated by PV is supplied to the grid through the shunt inverter while the series inverter as DVR operation injects the sufficient amount of voltage to the sensitive load as voltage compensation.

4. Proposed Operation of PV Inverters

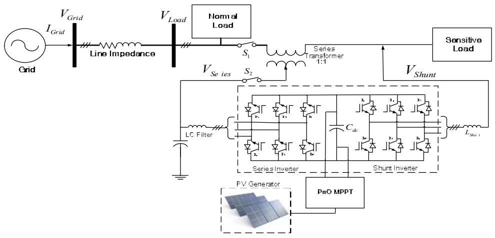


Fig. 3. Proposed PV converter with voltage compensation.

The proposed PV converter has the configuration of UPQC with back to back inverter. It consists of two inverters connected in series and shunt. The series connection inverter is the DVR configuration to mitigate the under voltage for sensitive load. The shunt inverter will inject the maximum active power during normal condition or when the series inverter is in on mode.

5. Simulation results

TABLE Ⅰ System Parameters

Part of Circuit	Descriptions	Value
Grid	Main Voltage	220;180;150 V 220;240;270 V
	Frequency	50 Hz
Under voltage Load	Sensitive Load Active	80 kW
	Sensitive Load Reactive	60 kVar
Over voltage Load	Sensitive Load Active	90 kW
	Sensitive Load Reactive	60 kVar
Converter DC	DC Capacitor (Cdc)	20 mF
PV System	Max Power	110 kW
	Open Circuit Voltage	675 V
	Short Circuit Current	168 A
	Vmpp	684 V
	Immp	180 A
Series Connection	Transformer	1:1
	Filter (Cse and Lse)	50μF, 1mH
	PI 1, PI 2, and PI 3	20
Shunt Connection	Lshunt	2mH
	PI 1 & PI 2(Islanded)	20
	PI 1 & PI 2(Power Mode)	200
PWM	Sampling Frequency	5 kHz

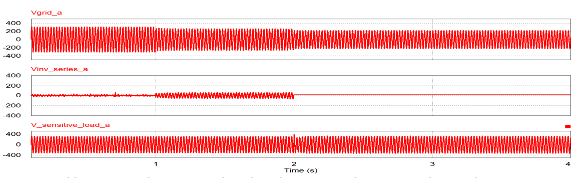


Fig. 4. Under-voltage simulation: grid, series inverter, and sensitive load.

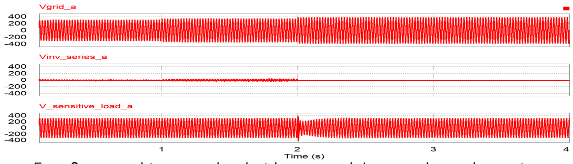


Fig. 5. Over-voltage simulation: grid, series inverter, and sensitive load.

Fig. 4 shows the voltage during under voltage condition. Before t<1s, the grid voltage is in normal condition, then no action from series inverter, while shunt inverter delivers active power to the grid only. Once the under voltage is detected (1s<t<2s) but still above 0.8pu, the series inverter injects the voltage to the sensitive load. However, the under voltage is below 0.8pu (2s<t<4s), the series inverter gives up the voltage compensation. Then the sensitive load is disconnected from the line grid and the shunt inverter supplies the power to the sensitive load directly.

Fig. 5 shows the simulation results of the grid voltage, the load. During normal condition, t<1, no over voltage from grid only shunt inverter injects active power to the grid. Time runs from 1 to 2s, the over voltage is occurred to 1.09pu and the series inverter compensates the voltage grid to follow standard magnitude voltage. Both of S1 and S2 are in on position. Moreover, when the over voltage is above 1.1pu (2s<t<4s), the shunt inverter will take care of sensitive load. In this condition, islanded mode will be transferred from grid connected.

6. Conclusions

Power quality related to submarine cable can be solved by the proposed method. Under the normal mode, shunt inverter injects power to the grid without any voltage compensation. In voltage compensation mode, the under voltage or over voltage are compensated by the series inverter and shunt delivers power to the grid simultaneously. In the stand alone mode, sensitive load will be fed directly from the shunt inverter without connected to the grid. This kind of technology can be applied to the isolated islands which is supplied power through the submarine cable.

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