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Reactive Power Management of Islanded Microgrid Using UPFC

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Abstract: This paper proposes an impact strategy to curtail the reactive power imbalance in islanded microgrid which results in the maintenance of voltage balance. The reactive power imbalance compensation is achieved by injection of an accurate synchronous voltage supply into the microgrid through the power electronics based converters. This task is done by advanced Flexible a.c transmission system (FACTS) device connected with Unified power flow controller (UPFC) to the microgrid. This compensation reference is obtained through a synchronous voltage management, avoiding the load frequency control loop. This strategy does not need any hardware modification. This management strategy is simulated in Matlab/Simulink to prove its effectiveness.

Key words: Microgrid, distributed generation systems, UPFC.

Introduction

In India, there are still many villages or isolated areas which are not electrically connected but to empower those deserted or isolated areas, the best solutions are microgrids. These microgrids can provide continuous and cost effective electric power to such areas. For such microgrids, the hybrid combination of non-conventional and conventional energy sources are advisable solutions because it produces cost effective and pollution reducing power. But power quality is the key issue in such type of microgrids and a typical disadvantage is the voltage imbalance.

Lots of analysis and research work has been done on this subject. Such microgrids feed variety of constant loads, dynamic loads and randomly variable loads; thus the currents delivered by the distributed generations are generally not balanced. Therefore, the voltages across the load impedances and consequently the different load voltages become unbalanced. Unbalanced voltages are resulted in mal-operation, especially for dynamic loads and increase losses in connecting machines.

Although every Distributed Generation (DG) unit among the microgrid try to impose a balanced voltages in the system, the presence of non-conventional energy sources bring lot of voltage variations in the system. Therefore, power electronics based convertor management strategies are implemented in the power system to maintain the output voltage balance. The inverters equipped with high rating thyristors (Bansal et al., 2003; Aekcrmann et al., 2001) will do balanced voltages as a result of this strategy controls the convertor output voltage and frequency. However, some unsteady sources, such as random electrical contingencies and fluctuating wind generation can require rigorous power electronics converters arrangement; as a result their goal is to deliver all offered power. This paper proposes a technique to compensate reactive power to maintain the voltage variations within the system consequently; it enhances the power system quality despite of connecting dynamic loads. The compensation is usually achieved for such hybrid power systems because the voltage imbalance is quite evitable in the RES driven microgrids caused by the variation in unbalanced load currents (Rodriguez et al., 2006). This demand of reactive power to maintain the voltage stability is usually provided locally at load centres. The presented compensation strategy depends on the injection of synchronous voltage source to the bus terminal (Azevedo et al., 2009). In this paper, following sections describe a brief discussion of the matter and a simulation model that proves the event of voltage imbalance due to unbalanced loads are presented. A powerful reactive power compensation strategy has been implemented to rectify it.

Unified Power Flow Controller

Flexible ac transmission system (FACTS) is a family of power electronics based controllers. Among the cluster of these controllers, Unified power flow controllers (UPFC) is termed as best Flexible ac transmission system (FACTS) controller. It is a multi-tasking controller which can regulate several actions at the same time such as control of transmission voltage, impedance, active and reactive power etc. (Gandhar et al., 2017). It can also provide a managed compensation to the power system. This is the advanced power electronic equipment which consists of two converters in shunt and series connections with the transmission line. It may be called a technical combination of a Static Compensator (STATCOM) and Static series Synchronous Compensator (SSSC). It can be used for the series of following contingencies of power system like power flow management, increasing transient stability and voltage (reactive power) regula-tion (Sadjad et al., 2014; Haddad et al., 2009).

The UPFC consists of two voltage-source converters (VSC), connected in antiparallel manner and a DC electrical condenser is placed in between those VSCs (Figure 1).

It injects a synchronous voltage supply of needed amplitude into the system. The function of series convertor is to inject synchronous voltages—V series with the line, which results in the flow of active power and generation of required reactive power into the system. The reactive power is domestically generated by the series convertor, whereas the active power is transferred to or from the line through the dc electrical condenser (Figure 2). In the meanwhile, the shunt convertor generates the need of this DC terminal

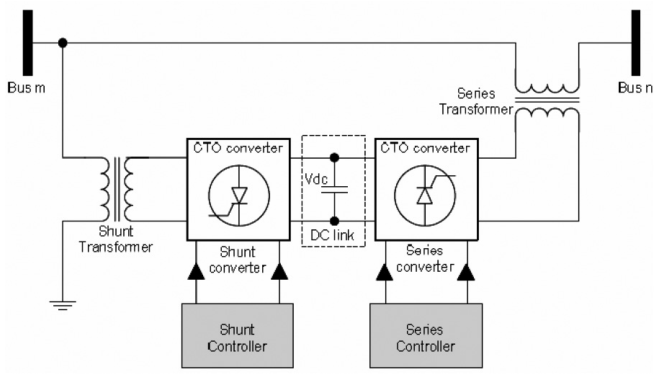

Figure 1: The schematic configuration of UPFC.

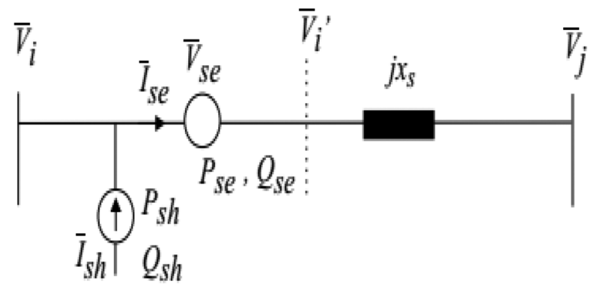

Figure 2: The electric circuit diagram.

power to or from the line, and thereby regulates the flow of active power of system. The total real power consumed by the UPFC at the expense of total losses of convertors and, therefore, the coupling transformers. The generation of reactive power is directly done by series and shunt convertors like a STATCOM. Therefore, reactive power compensation methodology of the shunt convertor is synonymous to standard STATCOM.

Simulation Test System

In this section, a test system of islanded microgrid is designed and all simulations have been carried out in Matlab/Simulink, where a microgrid was modelled by two three-phase generating source, modified 14-Bus system and some loads. The generating source used here are of two types, i.e. Doubly Fed Induction generator (DFIG) and Three Phase constant voltage sources connected at Bus-1. Similarly different types of loads are connected to different bus locations in the circuit. These types of loads are considered for simulation studies, i.e. Resistive-Inductive, Resistive-Capacitive, Purely Capacitive Loads and a combination of both inductive and capacitive loads. Power balance equations are considered for the simulation studies. Because of the presence of many inductive loads and the reactive power demand of DFIG it is highly desirable to connect the condensers in the system. But after observing the transient responses of the system, it is really impossible to balance the reactive powers of the system with these fixed capacitors; therefore a very powerful FACTS controller is connected in between the Bus-7 and Bus-8 and responses are collected and presented in the next section.

Simulation Results

The designed test system for reactive power compensation was evaluated in MATLAB in simulation set-up. It comprises the microgrid which was emulated by the doubly fed induction generator (DFIG) and an equivalent voltage source and a set of transformers emulating the micro grid line impedance (Figure 3). The system voltage at source 575 Vrms/50 Hz and different load banks are connected to the microgrid. Figure 4 represents the simulation set-up where the FACTS controller is employed in between Bus-7 and Bus-8. The system voltage source (at Bus-1) is 11 kVA. Once the different loads are switched on, the power profiles become utterly unbalanced. Initially, the system tries to balance the voltage and reactive power but static capacitors are unable to manage the imbalance of reactive power at various nodal points (Figure 4).

Simulation studies show the behavior of system imbalance of reactive power as shown in Figures 5 to 10 at 0 to 5 seconds. But after 5 seconds, UPFC has been connected into the system and once this compensation technique is employed, the voltage and reactive power has been improved. Moreover, it was conjointly discovered that the controller quickly starts to compensate the voltage and it stabilizes the reactive power within two seconds. Figures 5 to 10 shows the various active and reactive power responses of the system and powerful reactive power compensation capability of UPFC. All the power responses with and without controller are also tabulated in Table 1. It also has the inherent quality of balancing the active power of the system. It does so by inserting a synchronous voltage source into the system by comparing the terminal voltage with the bus voltages.

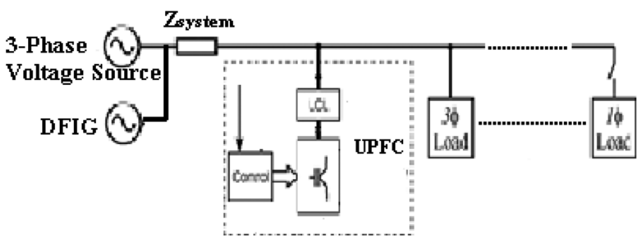

Figure 3: Simulation set up.

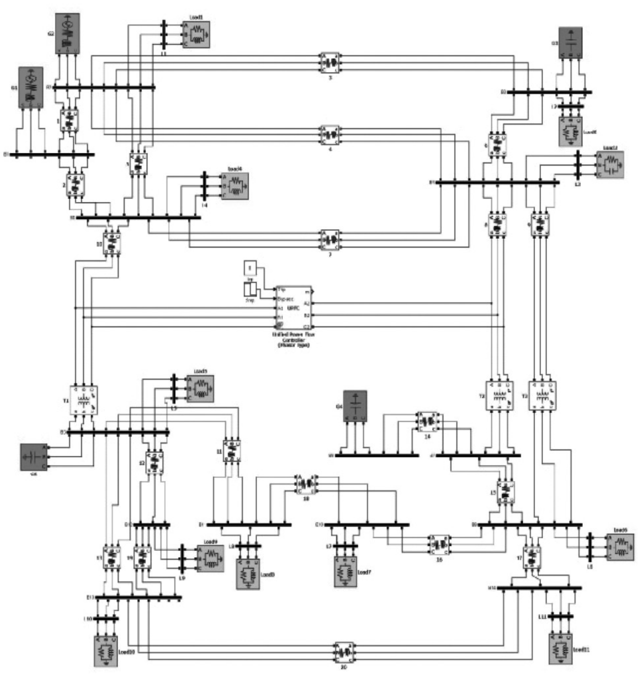

Figure 4: Simulink test system of islanded micro grid.

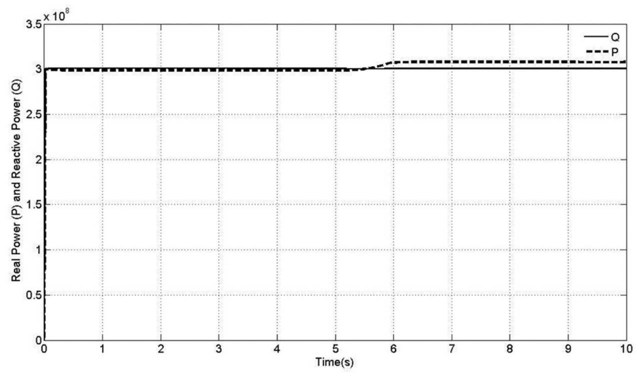

Figure 5: Reactive and real power at Bus-1.

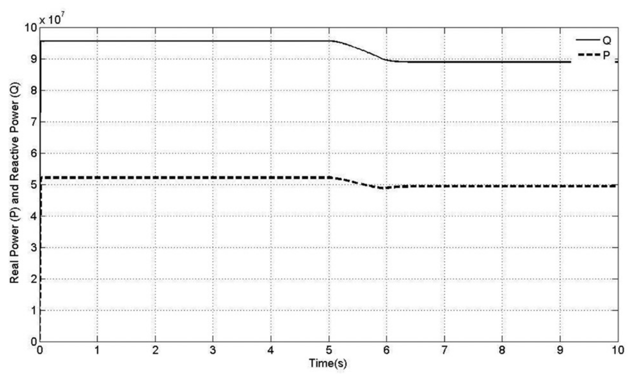

Figure 6: Reactive and real power at Bus-2.

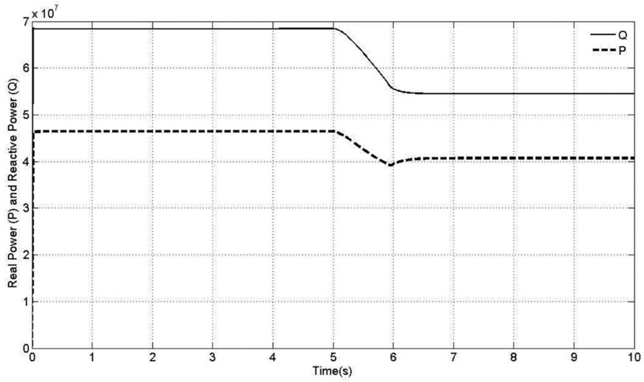

Figure 7: Reactive and real power at Bus-4.

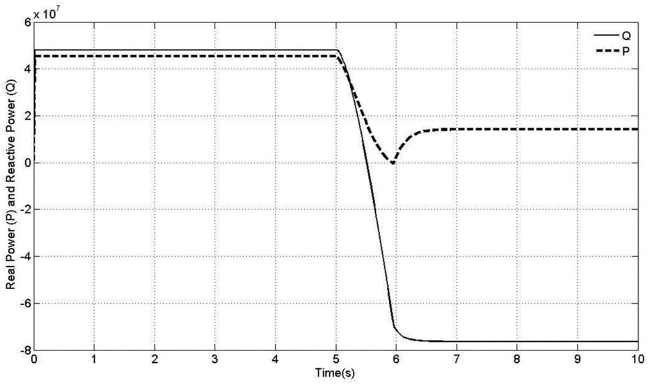

Figure 8: Reactive and real power at Bus-6.

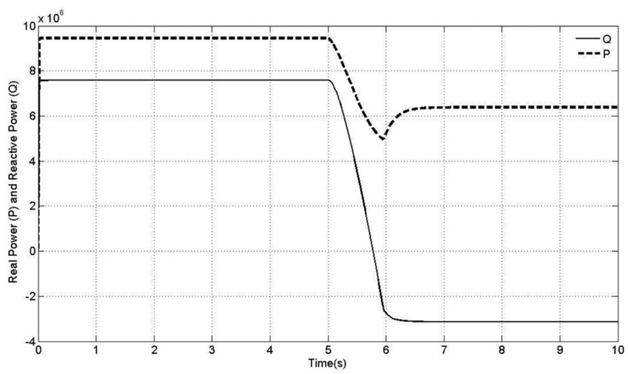

Figure 9: Reactive and real power at Bus-12.

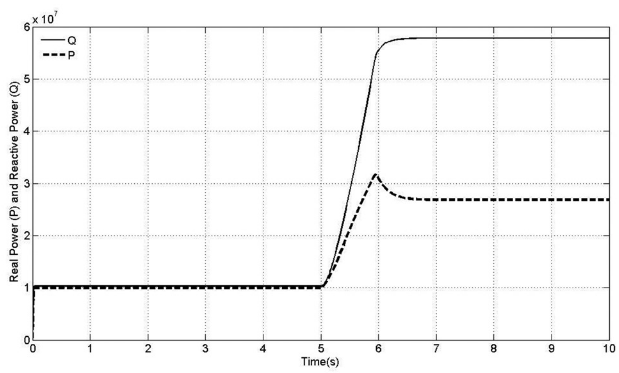

Figure 10: Reactive and real power at Bus-14.

Table 1: Real and reactive power of test system

Sr No.	*Bus/Node*	*Real and reactive power without UPFC (10^7)*	*Real and reactive power with UPFC (10^7)*
1	Bus-1	3+j2.9	3+j3.2
2	Bus-2	0+j1.5	0.7+j1.7
3	Bus-3	9.5+j5.5	9+j5.0
4	Bus-4	6.8+j4.6	5.5+j4.1
5	Bus-5	9.5+j7.9	8.6+j10.2
6	Bus-6	4.9+j4.8	-7.8+j1.6
7	Bus-7	-1.4+j2.4	-1.4+j2.4
8	Bus-8	-1.4+j2.4	-1.4+j2.4
9	Bus-9	2.5+j3.9	14+j9
10	Bus-10	0.2+j0.6	-6.9-j2.1
11	Bus-11	0.5+j1.1	-6.9-j1.1
12	Bus-12	7.+j9.5	-3+j6.1
13	Bus-13	1.7+j2.2	-2.1+j1.2
14	Bus-14	1+j1	5.9+j2.8

Conclusion

This paper proposes a reactive power compensation strategy to mitigate the unbalanced reactive power and voltages in islanded microgrids. This control technique can be highly beneficial in the Renewable energy sources (RES) based microgrids because those systems occur more prone to disturbances with the renewable sources. It is not necessary to have any extra measurement sensor; the simulation results show that the UPFC is really a very powerful compensator to manage the reactive power imbalances completely despite of having continuous fluctuations in the supply sources. Therefore, it is proved to be a very good solution for compensation in islanded microgrids.

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