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Designing Micro-Grid Static Switch in Reverse Power

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ABSTRACT: Static switch is placed between micro-grid and national power grid, and performs connection and disconnection of micro-grid to power grid. One important duty of static switch is to detect recursion of power (power reverse) from micro-grid to power grid. Reverse power refers to both active and reactive powers. In present paper, different cases of power recursion from micro grid to power grid are studied and simulated, and an appropriate accurate detection system is designed and simulated. Simulation results, verify the accuracy and authenticity of this system.

Keywords: Micro-Grid, Static Switch, Reverse Power.

INTRODUCTION

Nowadays, power quality, safety and reliability have significant importance in power network, such that a vast area of researches is allocated to these characteristics. Utilizing novel control method beside distributed generation sources by considering levels of safety, quality and reliability, creates a new concept called micro-grid. Micro-grid meets current needs of users and can deliver power to sensitive loads with high qualities (Rocabert et al., 2011; Casey et al., 2012; Eloy-Garcia et al., 2013). Each micro grid is able to operate in two islanded and power grid connected modes. In especial circumstances, micro-grid is separated of grid and gets into islanding mode, and will be re-connected to power grid via static switch (Mao et al., 2012).

Decision making in static switch control system is based on micro-grid policymaking. This policymaking is defined such that when micro-grid is faced with power shortage, then it will always be connected to power grid via static switch, and whenever it is able to supply the loads, it is isolated of power grid. This performance of static switch, is called reverse power recognition. One of the most important duties of static switch is to identify power reverse. In present paper, different cases of power reverse from micro-grid to power grid is investigated and by studying and simulating these different cases, an appropriate accurate reverse power recognition system in static switch is designed (Perkins et al., 1999; Liu et al., 2012; Katiraei et al., 2005; Zeineldin et al., 2006).

Static switch

Micro-grid is able to operate in two islanded and power grid connected modes. Static switch is located between micro-grid and power grid, which operation of ON/OFF from grid is done via this switch. Static switch has three duties in micro-grid: 1- To synchronize micro-grid with power grid 2- Identifying short circuit and separating micro-grid from power grid 3- To detect power reverse from micro-grid to power grid (Ustun et al., 2012).
Figure 1 illustrates position of a static switch in micro-grid.

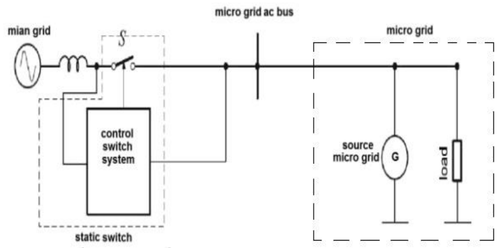

Figure 1. Position of a static switch in micro-grid

Micro-grid policymaking is based on the point that when power sources in micro-grid cannot supply their own loads, then static switch connects the micro-grid tower grid, so power shortage is compensated by power grid. When micro-grid sources are able to provide required power of micro-grid loads, then power flow from micro-grid to power grid is changed and so, static switch separates the micro-grid from power grid. Identifying power reverse from micro-grid to power grid, is one main important duty of static switch.

Computing the power

In a power system, apparent power in time domain, is obtained via relation (1):

$$S = V \times I^* \quad (1)$$

In fact, apparent power value is attained through multiplying voltage by current. If relation (1) is used to compute apparent power, then its real and imaginary parts equal to active and reactive powers respectively, as relation (2):

$$S = V \times I^* = P + jQ \quad (2)$$

Static switch must separate micro grid from power grid in two active and reactive power reverse. Power reverse in time domain is implemented in Mat lab as diagram block:

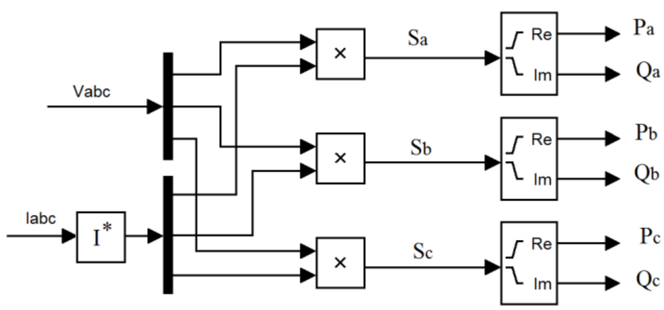

Figure 2. Diagram block of power computation in time domain

Powers obtained by diagram block (figure 2) are in form of sine waves and using such signals, makes it complicated to make decisions. Hence, d_q coordinate system is utilized in power systems simulation. This coordinate system, interprets equations of 3-phase system on axes q and d. In d_q coordinate system, equations are simpler and calculations are easily accomplished. After that if necessary, answers might be transferred into time domain.

If voltage and current in time domain are transferred into d_q coordinate system, then active and reactive powers are computed by relations (3) and (4) (Ma et al., 2012):

$$P = V_d \times I_d + V_q \times I_q \quad (3)$$

$$P = V_q \times I_d - V_d \times I_q \quad (4)$$

Decision making according to power value in d_q coordinate system, due to its linearity is so simple. Power is linear, since d_q coordinate system is rotating. Power computation diagram block in d_q coordinate system is implemented as figure 3 which relations (3) and (4) are exactly implemented.

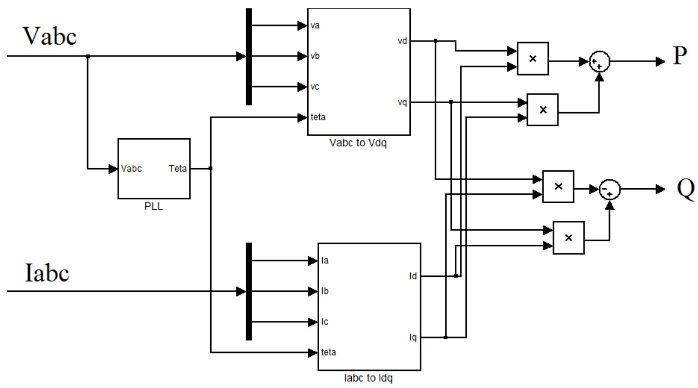

Figure 3. Power computation diagram block in d_q coordinate system

Power computations in d_q coordinate system are implemented in Matlab as figure 3. Voltage phase angles must be calculated to transfer time domain parameters into d_q coordinate system. As it is shown in figure (3), voltages phase angle is identified by phase-locked loop (PLL).

Reverse power relays

If current direction is determined, then it is possible to determine power flow direction as well. In this system, power flow direction is same as current's, since here it might be said that system voltage is independent of power flow. Operation of reverse power relays is based on current flow direction and by detecting current direction, power flow direction is determined as well.

In reverse power relays, sampling is performed for micro-grid 3-phase current. 3-phase current is transferred to Fortescue system by Fortescue transfer which includes three positive, negative and zero components. Considering location of sampler device, if power flow direction is from power grid to micro-grid, then domain of current's positive component has a magnitude, and if power flow direction is from micro-grid to power grid, then domain of current's positive component equals to zero. Hence, it is possible to determine current direction i.e. power flow direction here, by obtaining Fortes cue transfer (Ye et al., 2012; Bellini et al., 2012).

Due to economic issues, it is not recommended to uses these relays. These relays are too sensitive to partial instantaneous power reverse as well and in case of occurring some vibrations may some part of power returns to power grid and relay fails in decision making (Illindala et al., 2007).

If d_q coordinate system is used to compute the power, then it is possible to calculate power at any moment and also as average.

Simulation

Figure 1, is simulated as a power grid connected micro-grid sample which illustrates a simple modeling of micro-grid.

Power return determination system in time domain is designed and simulated based on third section descriptions and diagram block of figure 3. Figures 4 and 5 represent 3-phase voltage and current of static switch in normal performance respectively. Considering current in figure 5, static switch is in closed mode which indicates power flow from power grid to micro-grid.

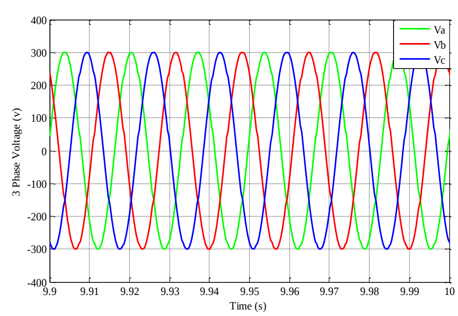

Figure 4. 3-phase voltage of static switch in normal performance mode

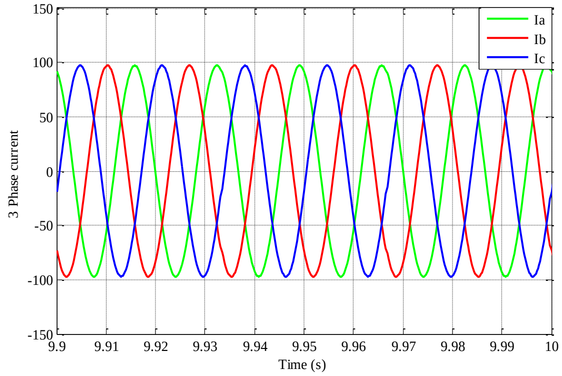

Figure 5. 3-phase current of static switch in normal performance mode

Apparent power is obtained via multiplying voltage by current. Real value of apparent power equals to active power and imaginary value of apparent power is equal to reactive power. Diagram block shown in figure 2, illustrates implementation procedure of active and reactive powers in time domain in Matlab. Figures 6 and 7 represent active and reactive powers in time domain corresponded to phase a. since current and voltage have a sinusoidal nature, then multiplication of voltage and current (i.e. power) is sinusoidal as well. As shown in figure 6 and 7, active and reactive powers computed in time domain also have sinusoidal nature.

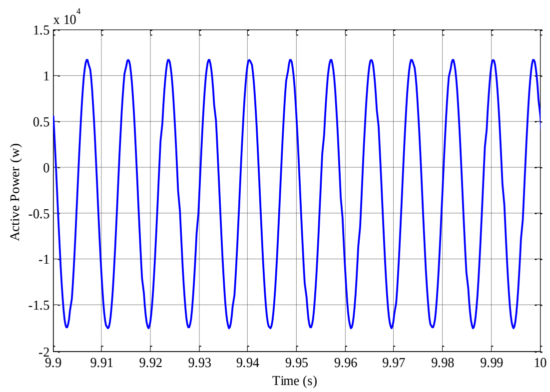

Figure 6. Active power passed through static switch in time domain

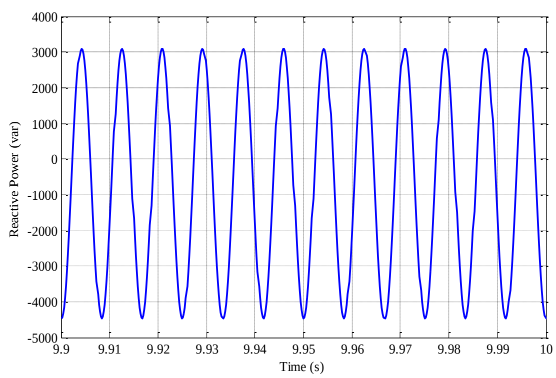

Figure 7. Reactive passed power passed through static switch in time domain

Power reverse recognition system of static switch is designed based on signal of passed power. Hence, power signals must be appropriate to be used in power reverse recognition system. Figures 6 and 7 illustrate this fact that active reactive powers are sinusoidal and it is difficult to determine power flow shift by these sinusoidal waves. Therefore, power computations are accomplished in another system so power reverse is easily recognizable.

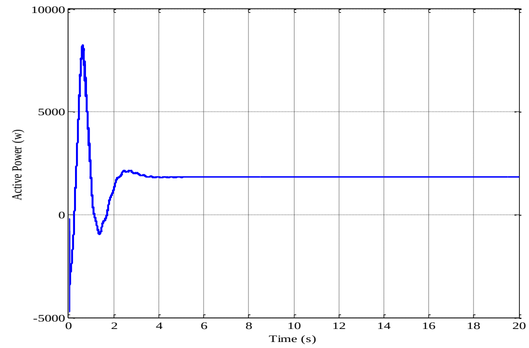

Figure 8. Active power passed through static switch in d_q coordinate system

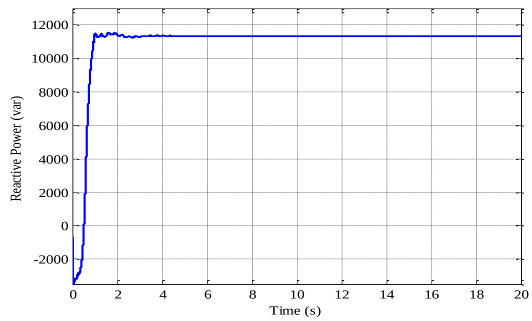

Figure 9. Reactive power passed through static switch in d_q coordinate system

Figure 9 and 10 indicate active and reactive powers passed through static key in d_q coordinate system. As it can be seen, active and reactive powers of micro-grid after passing beginning fluctuations, is linear. Since in d_q coordinate system, power waves shape is linear, hence these wave shapes are suitable for power reverse recognition system. This system is designed based on d_q coordinate system. Figures 10 and 11 depict active and reactive powers return respectively.

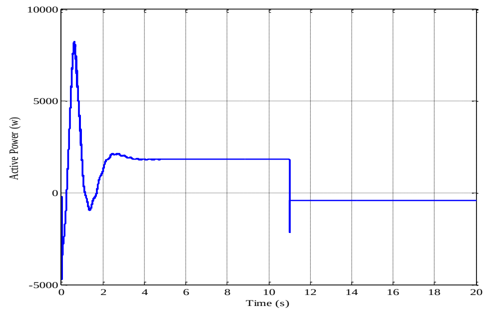

Figure 10. Active power reverse to power grid

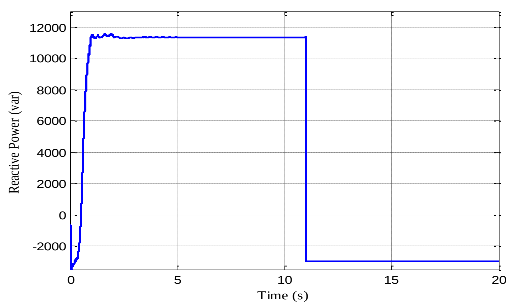

Figure 11. Reactive power reverse to power grid

According to figures 10 and 11, power reverse recognition system must be designed such that recognizes this recursion toward power grid and at the same moment, separates micro-grid from power grid.

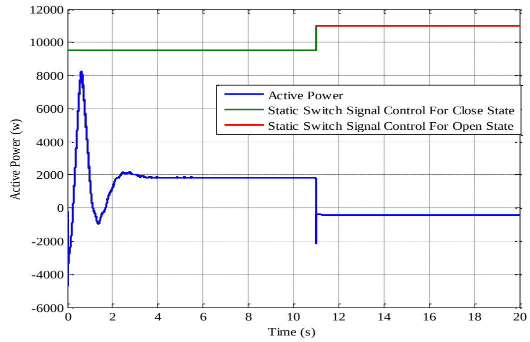

Figure 12. Active power reverse to power grid and static switch performance

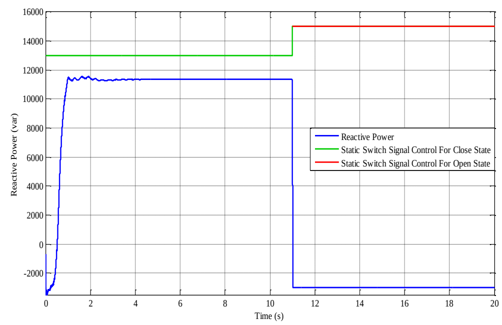

Figure 13. Reactive power reverse to power grid and static switch performance

Figures 12 and 13 represent performance of static switch against active and reactive powers return. As it is shown in figures 12 and 13, when power reverse towards power grid occurs, power reverse recognition system commands opening static switch by sending signal to switch. These two figures, depict appropriate precise performance of power reverse recognition system. Designed system detects active and reactive power and separates micro-grid from power grid in two modes.

CONCULSION

Since current and voltage wave shapes are sinusoidal, then active and reactive power wave shapes in time domain are sinusoidal as well. But in d_q coordinate system, active and reactive powers are linear, hence appropriate precise design of power reverse system is according to power computations in d_q coordinate system. When power flow direction is from power grid to micro-grid, designed power reverse system has no activity and in contrast, this system was able to recognize power reverse from micro-grid to power grid and commanded static switch opening. Present system recognized active and reactive powers reverse in two cases and disconnected static switch in return case accurately.

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