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# Power Management and Synchronization Control of Renewable Energy MicroGrid Based on STATCOM

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***Abstract*- A microgrid is an important component unit of future power grid. Its character is different from the grid itself and requires separated dedicated research. This paper mainly researches a microgrid system containing a diesel generator, two wind power generators, two loads and one STATCOM. The model is established, and the system character is researched in different scenarios. STATCOM can compensate the active and reactive power needed by the load and strengthens the system stability.**

## I. INTRODUCTION

The rapid development in exploiting renewable energy sources for electricity generation worldwide has led to the concept and realisation of distributed generation and supply networks, forming a microgrid. In general, a microgrid is a portion of a distributed grid capable of supplying its own local load in either grid-connected or autonomous modes of operation, by various distributed generation units. By its nature, such a grid is non-stiff, operates only in autonomous mode, and must satisfy the load requirement under all conditions. It is always challenging to maintain stable, efficient and safe operation of a microgrid. The challenge becomes greater when there is a high penetration of renewable sourced generators, such as those powered by solar and wind energies, due to their unpredictable and intermittent generating nature. Power management and synchronization control are more complicated in this microgrid than in the grid.

Controllable network devices such as the Static Compensator (STATCOM) can be used in critical parts of a microgrid to offer temporary real and reactive power compensations when necessary, hence increasing system power transfer capabilities and reliability. This paper presents a study of a particular microgrid under the compensation of a STATCOM. It consists of a diesel generator as the main power source, two wind power generators, a STATCOM, and two loads.The configuration and system architecture are detailed in section Ⅱ, and the control scheme in section Ⅲ. The simulation results verifying the performance of the system are presented in section Ⅳ. Conclusions are discussed in sections Ⅴ.

## II. STRUCTURE OF MICROGRID

The studied microgrid structure is shown in Fig.1. The

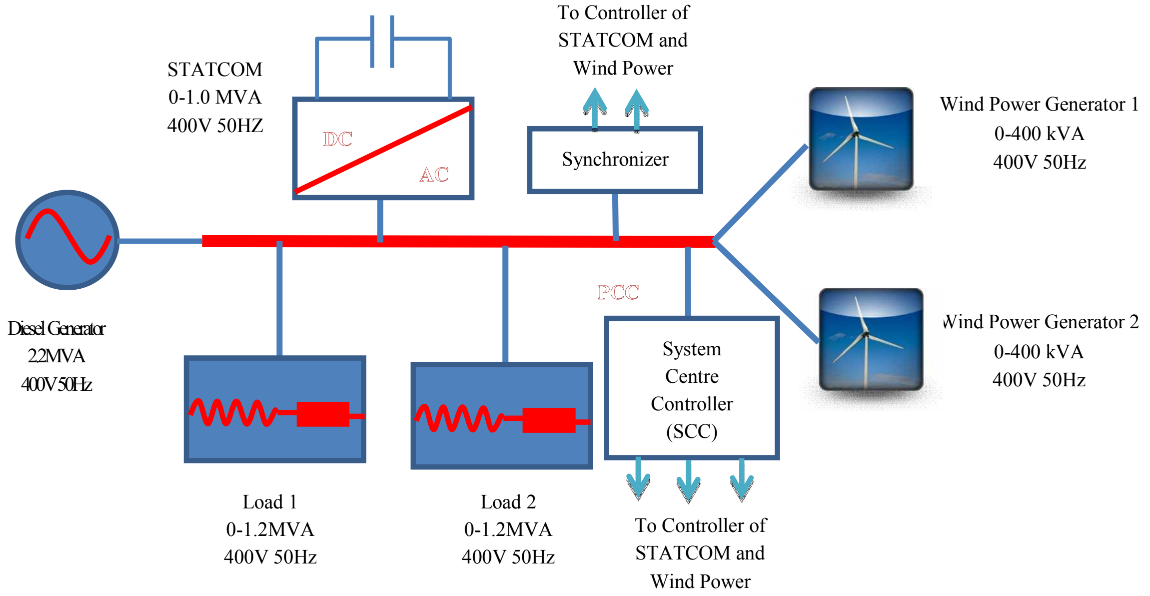


Fig.1. System Architecture

voltage of the system is 400V, 50 Hz, and the power rating according to the total nominal generating capacity is 3.0 MVA. The output terminals of the diesel generator are connected directly to the power line named as the Point of Common Coupling (PCC). Two wind power generators are identically rated at 400V and 400kVA and connected to the PCC through lines with negligible impedance. A STATCOM using a two-level DC-AC with a capacitor for energy storage is used in the system for real and reactive power compensation and is shunt connected to the PCC through a filter with R-L equals $4 * 10^{-4}\Omega$ and $3 * 10^{-5}$H. The two loads rated at 1.2MVA each are also connected to the system through transmission cable directly with negligible impedance.

This system is designed to operate in the following principle and manner: the diesel generator is always running and is maintaining a nearly constant system voltage and frequency, even when it is supplying zero real power. When there is significant wind available, the wind generator output inverter voltages are adjusted so that as much as possible of the load is supplied by the wind, hence minimising oil consumption by diesel generator. However during the transient of a sudden load variation, the wind generators may not be able to offset the power imbalance and the diesel generator cannot respond fast enough. The STATCOM, which has rapid response, would be able to react promptly to supply the power shortage, or absorb the power surplus, for a time until the diesel generator is able to respond, hence maintaining frequency and voltage at the required levels. In normal operation, when the real power is balanced, the STATCOM may supply or absorb reactive power to maintain the PCC voltage at the required level.

As will be seen below, this desired operating mode can be obtained using a system central controller (SCC) which is the power flow manager of the whole system and regulators for individual generators in the microgrid which are all carefully tuned for fast and accurate responses to system frequency and voltage changes.

Synchronization is the most important issue in AC system. It is the premise and base to keep the whole system to work safely and properly, especially for this microgrid in which the diesel generator is the main source to keep the PCC voltage stable and the synchronization signal is easy to be disturbed.

## III. SYSTEM CONTROL AND SYNCHRONIZATION SCHEMES

### A. *System Centre Controller (SCC)*

As shown in Fig.2, the SCC is located between the controller of the power source and the controlled elements. It measures the power requirement from the loads and the supplying ability of all power resources firstly. Then it will allocate the power according to the above principle and manner (Section Ⅱ). The SCC does not measure and control the diesel generator, but the diesel generator is controlled through droop control of the frequency and voltage of the PCC after the SCC work.

The SCC principle is realized based on d-q transformation, shown in Fig.3. Firstly, it measures the current needed by the loads and translates it to d-q values as the active power and reactive power requirement. The reactive power needed by load will be allocated to STATCOM. If wind power generators can offer the active power that the load needs, the power will be allocated to them directly, or the part power will be allocated to wind power generators according to their output ability and the other will be sent to STATCOM.

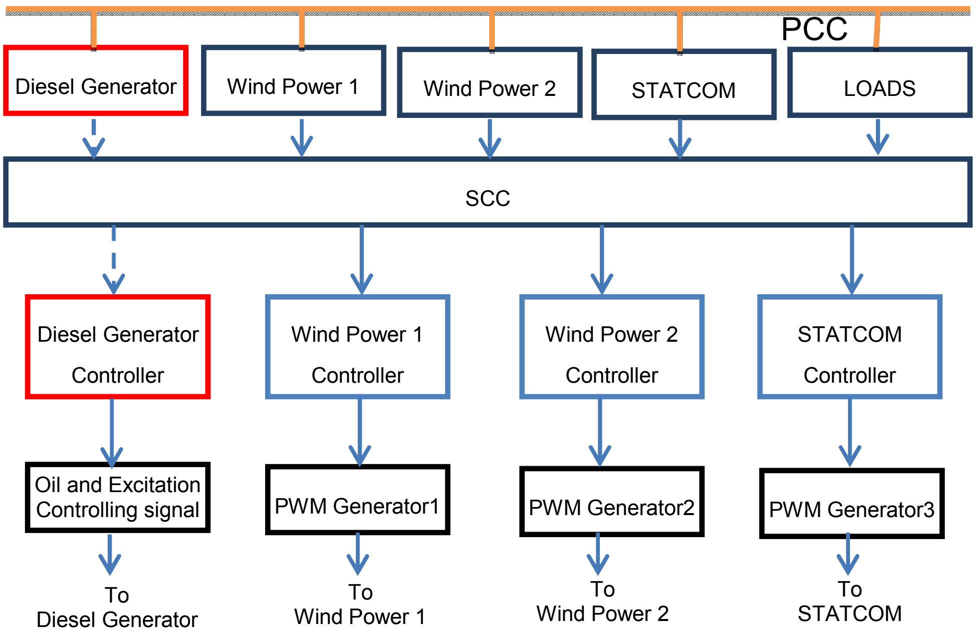


Fig.2. System Control Architecture Based on SCC

Because STATCOM's compensating ability is limited, the diesel will give more energy to keep the power balance through frequency and voltage droop control.

*B. Synchronization System*

As shown in Fig.4, the synchronization system applies PLL technology to extract synchronizing signal sin$\theta$ and cos$\theta$ which are needed by all the other subsystems for d-q transformation. Because of the diesel output voltage and frequency fluctuation, a 2nd-order low pass filter module is used before the 3-phase PLL to keep the following speed and precision, which will filter out the high frequency and pulse component of the PCC voltage caused by the diesel engine perturbations.

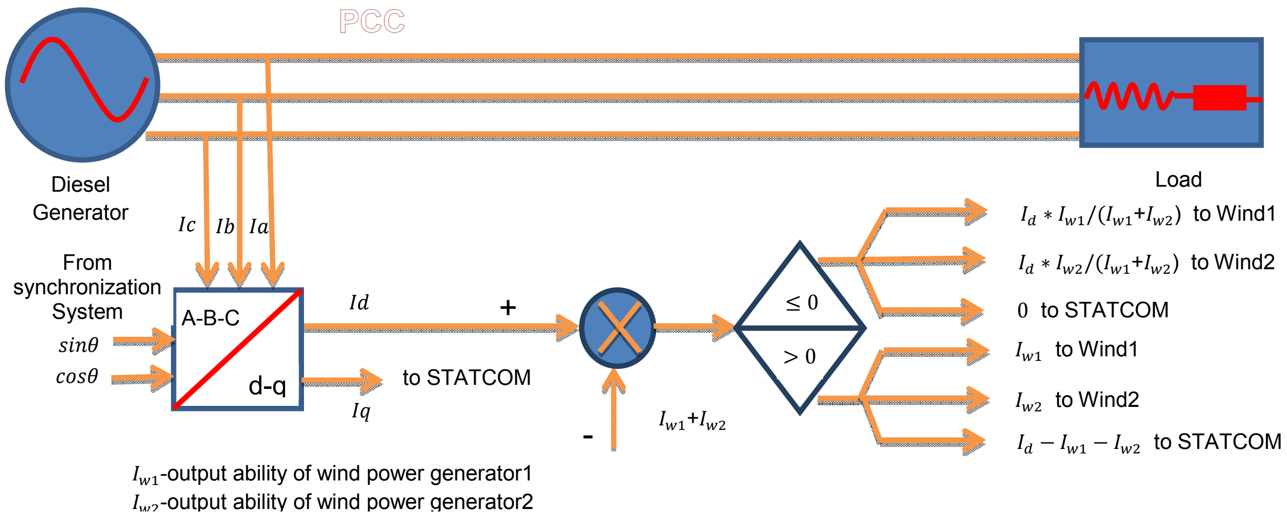


Fig.3. Model of SCC

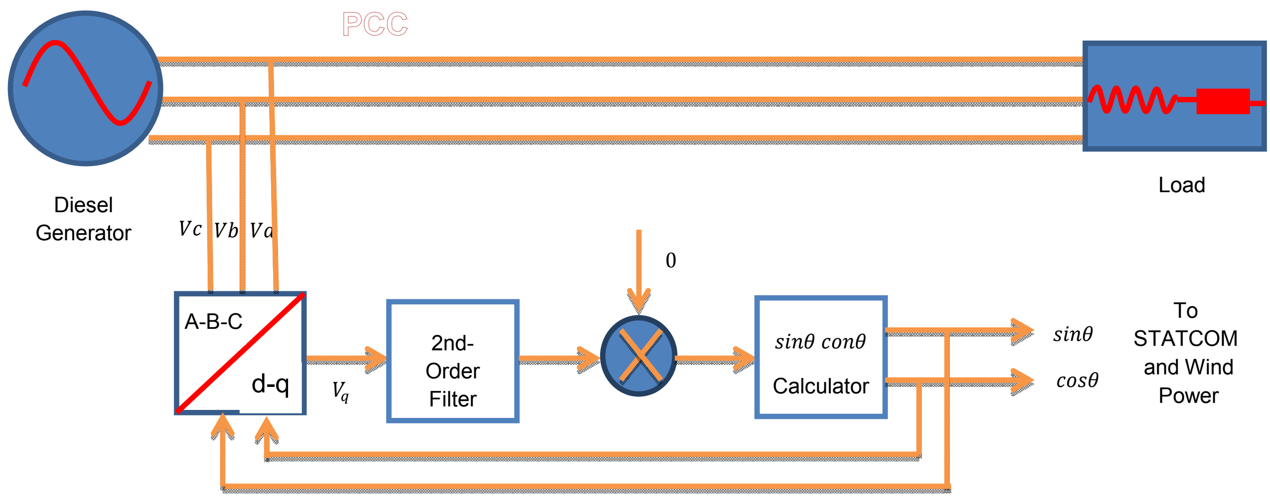


Fig.4. Model of Synchronization System Based on PLL

*C. Control System of STATCOM*

Based on the principle [1], the model of the STATCOM inverter controller is shown in Fig.5. It adopts droop control technology and uses the freuency and voltage of the PCC, the voltage of the capacitor, and the active and reactive power demand of the load (coming from SCC) as input parameters of the PI controllers. The frequency and voltage of the PCC are used to compensate the active and reactive power need of the PCC. The capacitor voltage is used to control the capacitor voltage stable. Active and reactive parameters of the load are used to compensate the active and reactive power need of the load. The system architecture adopts series and parallel of the PI Controller.

The PI controller is used to control the current in order to get the realistic voltage and keep the tracing velocity. With a damping ratio of 0.7, a closed loop bandwidth of 110Hz and a response time 0.1s (about one twentieth of the diesel response time), the resulting current controller is given Kp=2~5, Ki=15~40[1]. The parameters of the other PI controller are in table 1.

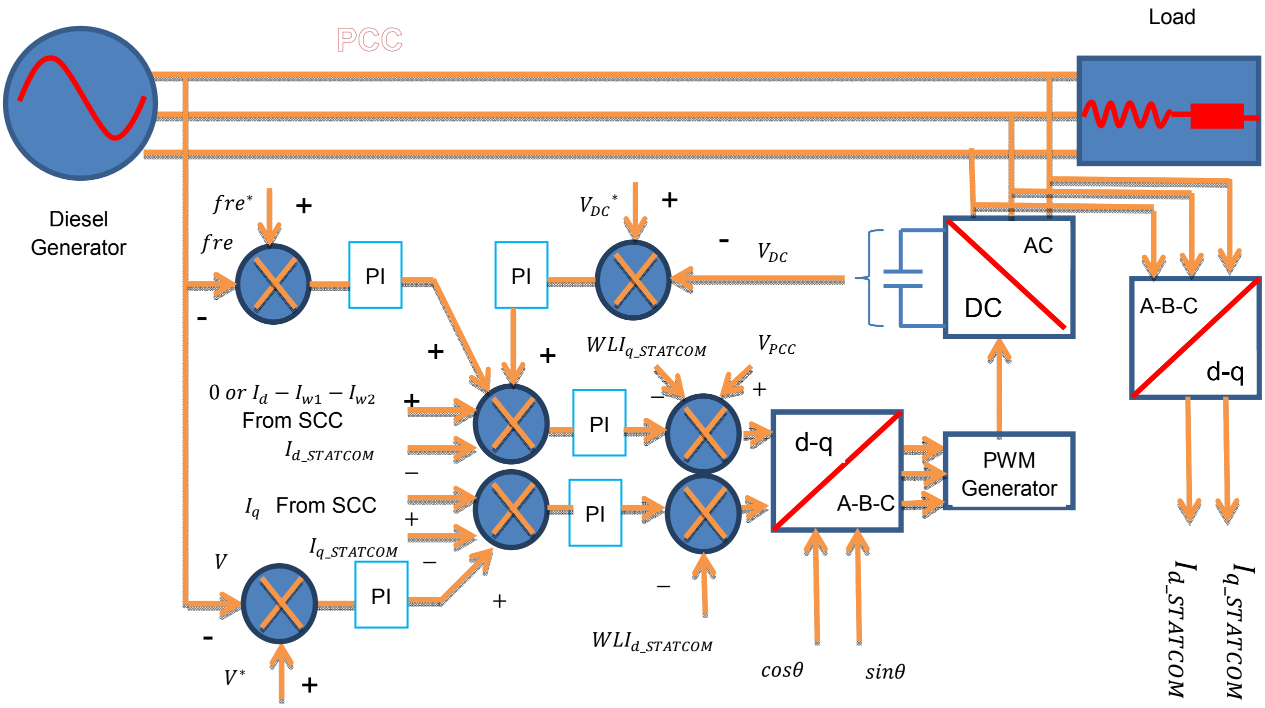


Fig.5. Controller for STATCOM

TABLE 1

THE PARAMETERS OF THE OTHER PI CONTROLLER

| PI Controller | Kp | Ki |
|---|---|---|
| PCC Frequency PI Controller | 2~10 | 8.5~50 |
| PCC Voltage PI Controller | 1.2~4 | 10~30 |
| Capacitor DC Voltage Controller | 5~20 | 30~15 |

## *D. Control System of Wind Power Generator*

The wind power generator DC-AC controller architecture is like that of STATCOM. The difference is in the PI controller input. Because the wind power generator is used just to offer active power, its input parameters include only the voltage of the capacitor, the active power demand of the load (coming from the SCC). The capacitor voltage is used to maintain the capacitor voltage stability. The active power demand of the load is used to compensate the active power requirement of the load. The parameters of the d current and q current PI controller are Kp=2~5, Ki=15~40[1]. And the parameters of the capacitor DC voltage PI controller are Kp=5~20, Ki=30~150.

# IV. Simulation Results and Discussions

## *A. Running process and operating scenarios*

The first part in the system running process is the start of the diesel. It needs about 1.0s to reach its balance, which will keep stabilization of the voltage and frequency of the PCC. The wind power and the STATCOM will connect to the PCC at 1.1s, which will give a big surge to the diesel control. The system remains stable because the surge is very short (about 0.002s). The first load will connect to the system at 1.2s and the other at 1.6s. The controlling system then begins to work and creates system power balance.

Four operation sceneries are set to verify the system character.

(1) The rating power of the wind power generators is set to 80kVA each (Active Power 80kW、Reactive Power 0 kVar). The loads are set to 50kVA each (Active Power 80kW、Reactive Power 0 kVar). Because this power can be supplied by the wind power system, the diesel and STATCOM will not offer power.

(2) The rating power of the wind power generators is set to 300kVA each (Active Power 300kW、Reactive Power 0 kVar). The loads are set to 900kVA each (Active Power 800kW、Reactive Power 100 kVar). Because this power cannot be supplied only by wind power system, the STATCOM will compensate the remaining power and then diesel begins to offer power.

(3) The rating power of wind power generators and loads are set the same as scenerie 2. The difference is that STATCOM doesn't work. Because this power cannot be supplied only by the wind power system, the diesel directly offers the remaining power.

(4) The rating power of the wind power generators is set to 400kVA each (Active Power 400kW、Reactive Power 0 kVar). The loads are set to 1400kVA each (Active Power 1200kW、Reactive Power 200 kVar). Because this power

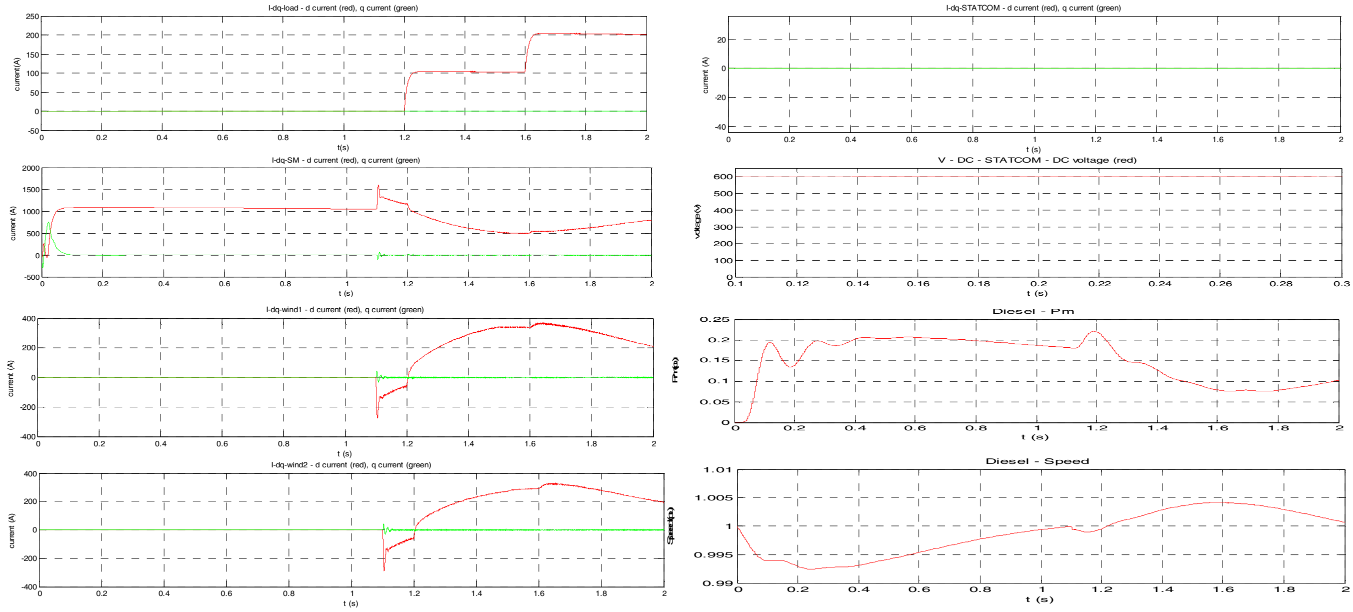


Fig.6. Simulation results of Scenario 1

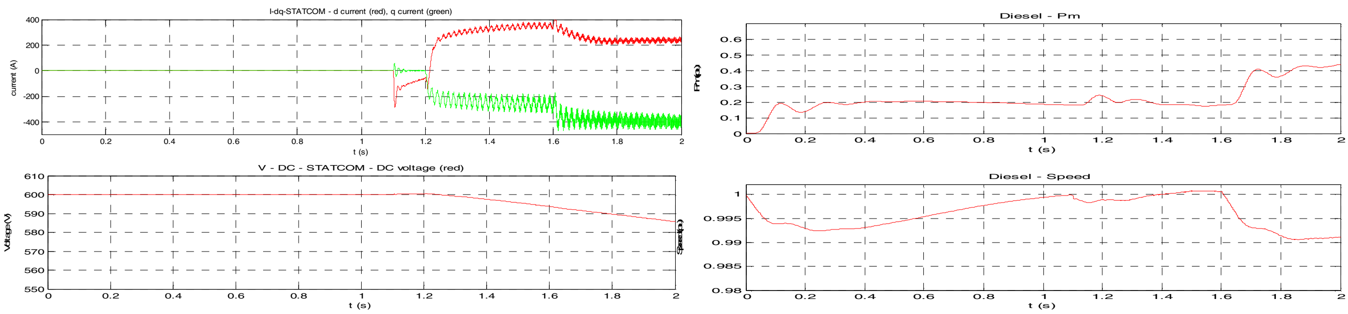


Fig.7. Simulation results of Scenario 2

cannot be supplied only by the wind power system, the STATCOM will compensate the remaining power and then diesel begin to offer power. The diesel speed will be affected seriously because of the heavy power requirement.

*B. Simulation results of Scenario 1*

Results are shown in Figs.6. The speed of the diesel will not reduce when the power needed by the load can be offered by the wind power generators. The speed rises slightly because the wind power generator can offer more energy to the PCC, which lightens the load on the diesel. The STATCOM does not work and the voltage of its capacitor will keep balance.

*C. Simulation results of Scenario 2*

The result is shown in Fig.7. The load is heavier than what wind power can do, so STATCOM will compensate the power left by wind power generator, the diesel will increase mechanical power to offer more energy. The wind power generators give what they can do to PCC. The speed of diesel will fall down when loads connect to PCC. STATCOM can compensate the active power when load 1 connects to PCC, but can’t compensate when load 2 connects to PCC because the voltage of capacitor fall down more. It needs to be

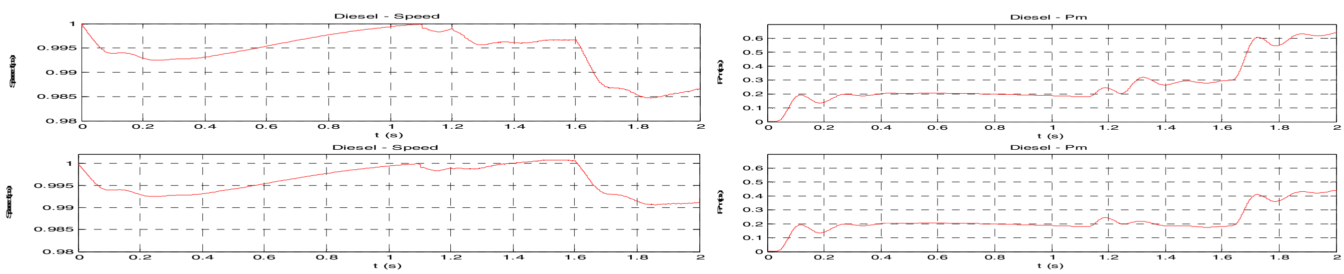


Fig.8. Simulation results of Scenario 33

discharged.

*D Simulation results of Scenario 3*

The working situation of this scenario is like that of scenario 2 except that STATCOM doesn't work but it works in scenario 2. The result is shown in Fig.8. The load is heavier than what wind power can do and STATCOM doesn't work, so diesel will offer the power left by wind power generator. When load 1 connects to PCC, the speed of diesel will fall down more than that in scenario 2. When load 2 connects to PCC, the speed of diesel falls the same like that in scenario 2 because of the voltage of the capacitor falls too more and needs to be discharged from diesel. The wind power generators give what they can do to PCC. The STATCOM output zero and the voltage of its capacitor keeps about 600V. Because of leakage current, the voltage falls a tiny bit.

*E. Simulation results of Scenario 4*

The result is shown in Fig. 9 The load is heavier than that of Scenario 4, so the system running progress is like that of scenario 4 except that the speed falls more.The loads increase more than Scenario 2, STATCOM can't compensate the power left by wind power generator. So the diesel's speed will be affected seriously because of the heavy power requirement.

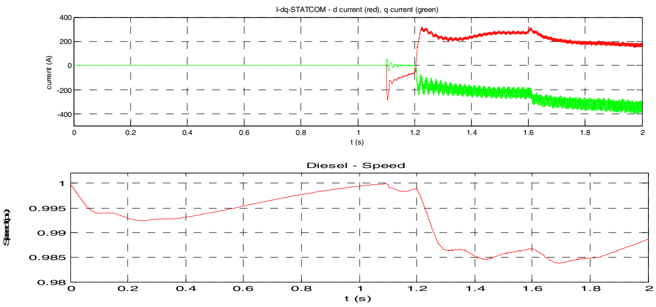


Fig.9. Simulation results of Scenario 4

## V. CONCLUSION

The system can simulate the microgrid's character based on the diesel and wind power and STATCOM. The simulation results have verified that it can work properly. The STATCOM strengthens the system stability.


## ACKNOWLEDGMENT

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