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Control Schemes for Distribution Grids with Mass Distributed Generation

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ABSTRACT

This paper discusses the control schemes for distribution grids with a large amount of wind penetration. Microgrids are constantly gaining popularity, especially in the countries, where there is energy crisis. They are an effective way for providing power to local loads. In case of main grid failure, they ensure smooth and seamless power transfer. Various electrical systems, including synchronous generators, grid and loads, have been investigated in this paper. All simulation work is carried out using SimPower Systems. Major focus is placed on active and reactive power sharing. Load transients have also been modelled. Moreover, power sharing under variable wind has also been simulated and analysed.

Keywords: *Distribution grids, synchronous generator, active power sharing, reactive power sharing, load transients, wind power*

1. INTRODUCTION

As the power demand is constantly increasing, the importance of producing more energy cannot be neglected. In this regard, microgrids, also known as distributed grids, are of utmost importance. They are a good means of providing energy to the network in case the main grid fails. This paper deals with the control schemes for distribution grids with mass distributed generation. It is likely that in near future, there will be more reliance on distributed generation, especially at low voltage (LV) and medium voltage (MV) levels. Such systems will increase the overall stability and reliability of the power network and at the same time, will provide more efficient performance. In simple words, if there is any fault on main grid and it is tripped, the microgrid does not disrupt power flow and continues to supply power to the consumers.

2. METHODOLOGY

The paper will elaborate how to develop the control methods for microgrids under high levels of distributed generation which, in case of this paper, is wind power. To achieve this aim, the software called SimPower Systems has been used. It is basically a part of MATLAB software. Several basic systems have been built which have been expanded to get the final model. Load transients and power sharing have been investigated. Finally, the wind power (constant and variable) has been introduced in the system and consequently, active and reactive power sharing have been explored.

At each stage, behavior of different parameters like voltages, currents, active power, reactive power etc. has been observed and plotted. Wind power has been used as distributed generation source.

3. LITERATURE REVIEW

Microgrids provide more efficiency and reliability in the power network. Efficiency can be considerably enhanced using Combined Heat and Power (CHP) techniques. Piagi and Lasseter [1] have found that during control mode of microgrid, there must be some energy balance between power supply and demand. This is possible by dispatching generators and/or loads. They [1] have proposed a micro-source control scheme for facilitating seamless mode transfer between grid and microgrid. It means in case of a fault, power can be rapidly detached from grid and shifted to microgrid. The authors [1] have used power-frequency droop to implement this. Similar idea will be used in the present paper to investigate power sharing between the two synchronous generators.

They have carried out a case study on University of Wisconsin microgrid to demonstrate the practical implications of island (grid disconnected) and grid connected modes [1].

S. Krishnamurthy et al. [2] have studied the operation of diesel engine fed synchronous generator sets as distributed generation sources. They found that controlling the reactive power-voltage droop characteristics is very essential; otherwise large reactive currents would flow in the synchronous generators.

Ling Su et al. [3] carried out studies on the microgrid control schemes using two micro-turbines as micro-sources. They slightly changed the way the droop parameters are designed. They enforced a limit on the active power output so that when power is at the maximum value, frequency is at its minimum value and vice versa. Yong Xue et al. [4] designed a control scheme to control the active power in a distributed generation unit in grid connected mode. Similarly, Basak P et al. [5] have discussed the control techniques for island mode of microgrids. One major conclusion drawn from their work is that when microgrid is operating in island mode, all non-critical (traditional) loads are eliminated automatically. Zhang Jie et al. [6] have used the inverter control technique for microgrid control. This is the most common control technique. They also studied the transition between grid connected and grid disconnected mode. They have used Voltage Source Inverter (VSI) as micro-source. Wei Huang et al. [7] have studied seamless transfer between grid-connected and grid-disconnected mode using Silicon-Controlled Rectifier (SCR) trigger control.

4. MODELLING ND SIMULATIONS

4.1 Grid and synchronous generator

Firstly, the system consisting of a main grid, a synchronous generator and resistive load is investigated using SimPower Systems. The block diagram is shown in Fig. 1

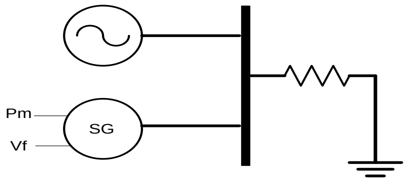

Fig. 1 Main grid and synchronous generator modelling

Referring to Fig. 1, the three-phase voltage source acts as the grid. Its rated line to line rms voltage is 11 KV. It is rated at a frequency of 50 Hz. Its internal resistance and inductance is 0.00001 Ohms and 0.04 H respectively. It is internally grounded.

The synchronous generator is rated at 1.5 MVA, 11 KV (line to line rms) and 50 Hz. It has 4 poles and has a cylindrical rotor. It has 2 inputs. One of them can either be mechanical power Pm or the speed and the other one is the field voltage Vf. In Fig. 1, mechanical power Pm and field voltage Vf are the inputs. The input mechanical power is 0.5 MW. Field voltage is controlled using a suitable PI controller in such a way that Vf produces nominal terminal voltage (which is 11 KV in this case). The same parameter values are used in all models.

At t=0, generator is connected to the system and it starts to operate as soon as the simulation starts.

The load is resistive. It is adjusted to absorb a load power of 1 MW. The line to line bus rms voltage is nearly 11 KV.

The speed of the synchronous generator is 157 radians/second. It is because the main grid (three-phase voltage source) sets the frequency of the generator in this case and hence, the generator runs at 157 radians/second. In technical terms, the grid is acting as the “Master” and the synchronous generator is acting as the “Slave”.

Active powers of synchronous generator and grid are equal to load active power (which is 1MW in this case). Sharing of active and reactive powers is verified graphically (See Simulation Graphs Fig.6, 7, 8, and 9).

4.2 Two synchronous generators and load

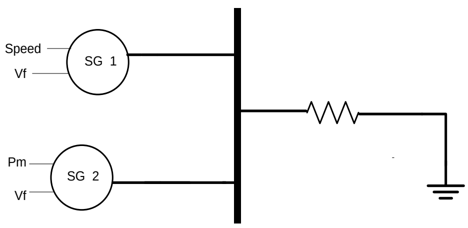

Fig.2 Power sharing between synchronous generators

In this case (refer to Fig.2), load power is kept the same (1 MW) and power sharing is observed between two synchronous generators. Synchronous Generator 2 (SG2) is made to run at 0.5 MW. Therefore, SG1 also runs at 0.5 MW to supply the load 1MW. In other words, SG2 and SG1 share the load power. Reactive powers of SG1 and SG2 add up to zero as the load is purely resistive. Sharing of active and reactive powers is verified graphically (See Simulation Graphs Fig.10, 11, 12, and 13).

4.3 Load transients

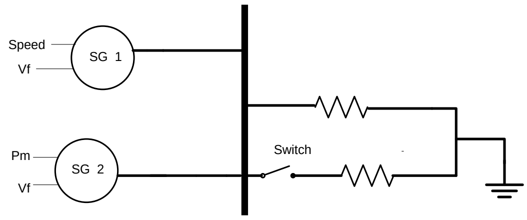

Fig. 3 Load transients

Referring to Fig.3, let us assume that a resistive load (of 1 MW) comes into the system after 2 seconds. In this case, the total load power is obviously 2 MW. So, SG 1 supplies 1.5 MW and SG 2 supplies 0.5 MW. It is because we are forcing SG 2 to run at 0.5 MW. If, for example, we make it run at 0.7 MW, the other generator will supply the remaining 1.3 MW to make the load active power equal to 2 MW. This resistive load transient is graphically shown in Fig.4

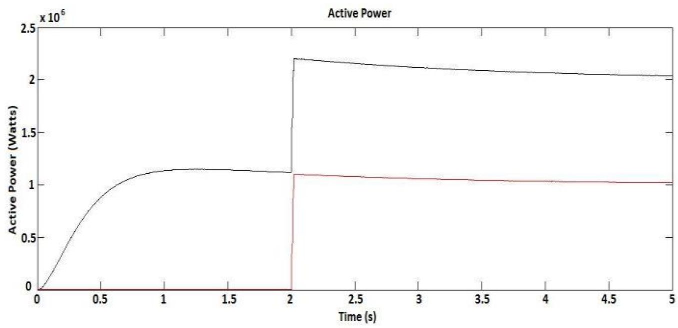

Fig.4 Resistive load transient after t=2 seconds

4.4 Variable wind power

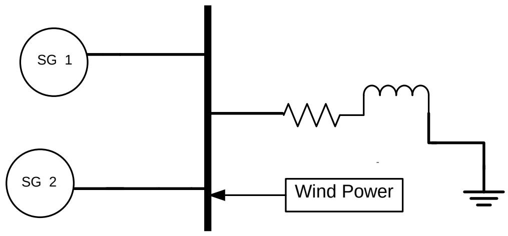

Fig.5 Introduction of variable wind power into the system

In order to see the effect of variable wind on the system and how active powers are shared, Id was input as a variable wind data. Iq was set to zero. The table of data (Table I) used as wind input is shown in Appendix. This data is used to just observe the trend when wind speeds increase or decrease.

Actual data may be ranging from 100 to 200 seconds but for simulation purposes, the data for 1 second is observed at the intervals of 0.1 second. The simulink model of Fig. 5 was simulated for 1 second.When the wind speed increases (up to 0.7 second), there is a droop in the active power of SG 1 and when the wind speed decreases (after 0.7 second), the active power of SG 1 starts to increase gradually. In other words, when there is a good availability of wind, SG 1 droops accordingly and the power requirements of the load are fulfilled by the wind and when there is low availability of wind, SG 1 provides the required load power. It must be noted that SG 2 is supplying constant power of 0.5 MW, therefore, changing wind speeds has no effect on it. (See Simulation Graphs Fig. 14 and 15).

5. SIMULATION GRAPHS

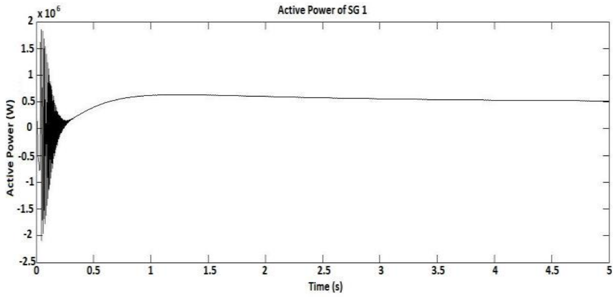

Fig. 10 Active power of SG 1 (0.5MW)

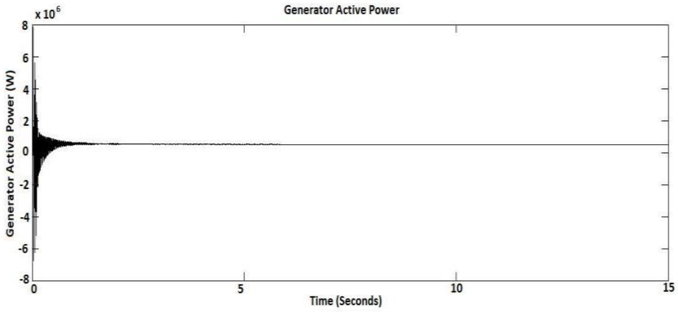

Fig. 6 Generator active power (0.5 MW)

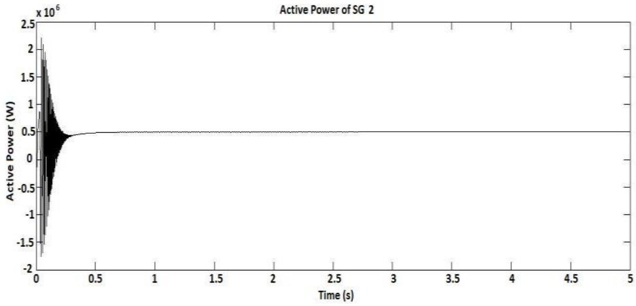

Fig. 11 Active power of SG 2 (0.5MW)

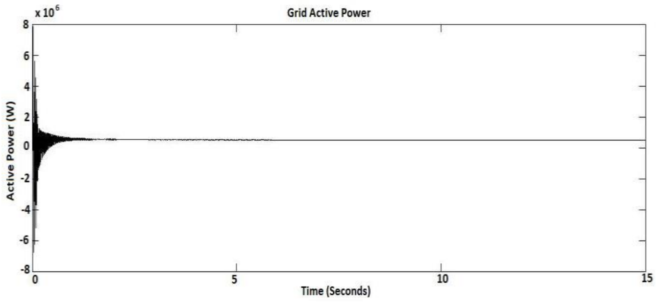

Fig. 7 Grid active power (0.5 MW)

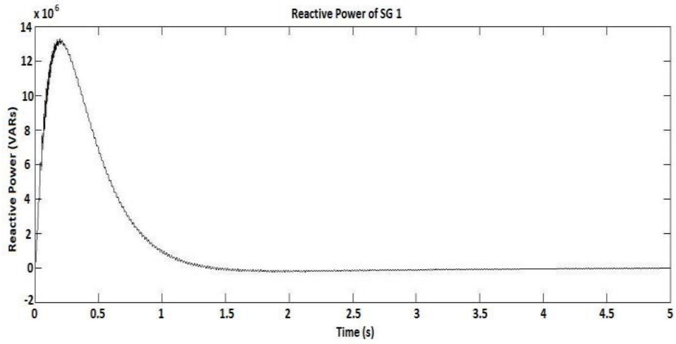

Fig. 12 Reactive power of SG 1 (-21 KVARS)

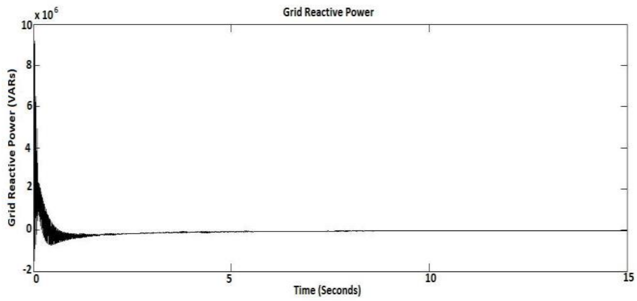

Fig. 8 Grid reactive power (-36 KVARS)

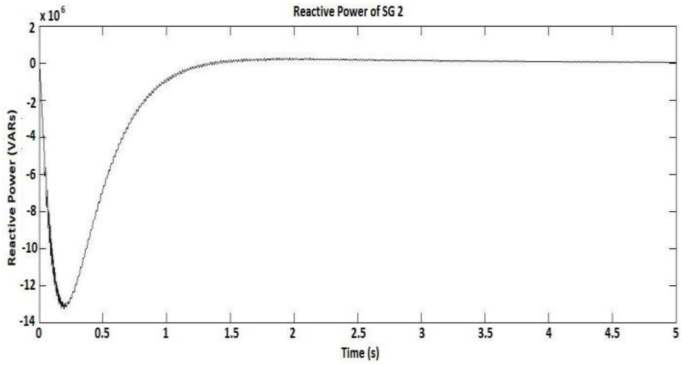

Fig. 13 Reactive power of SG 2 (21 KVARS)

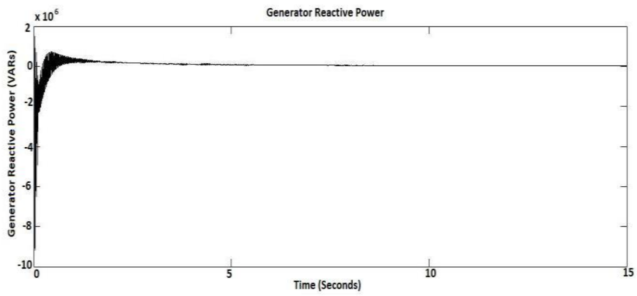

Fig.9 Generator reactive power (36 KVARS)

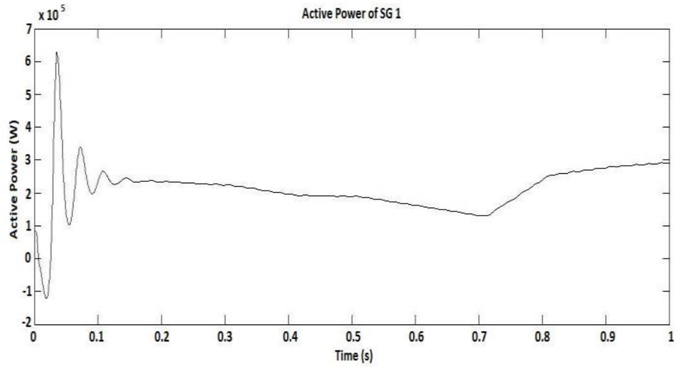

Fig. 14 Active power of SG 1

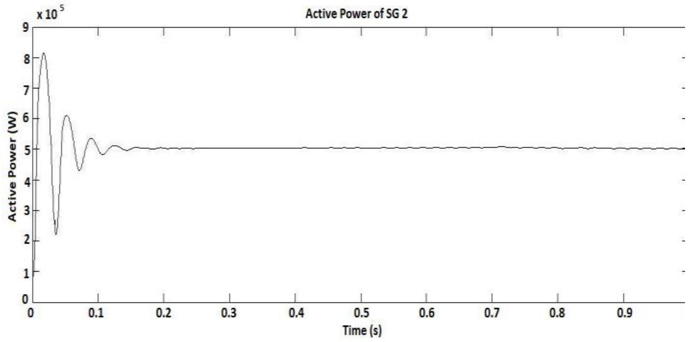

Fig. 15 Active power of SG 2 (0.5 MW)

6. CONCLUSION

The paper presented the major simulations leading to the microgrid implementation. Active and reactive power sharing was observed for multiple synchronous generators. Resistive load transients were investigated. Moreover, the behaviour of the system was studied under wind penetration. Active and reactive power sharing was observed under variable wind conditions. In short, microgrids are an effective way of providing electric power to the consumers without disruption. This technology is relatively new and has been implemented in a few countries like USA, Japan and Canada, but in the long run, it will surely benefit all kinds of consumers and this technology is here to stay. Further know-how about this technology should be inculcated into the people by the energy sector experts and they should make them realize the importance of using this.

APPENDIX

Table I. Wind speed data

Time (s)	Wind Speed (m/s)
0.0	13.2
0.1	13.9
0.2	14.2
0.3	14.8
0.4	16.5
0.5	16.7
0.6	18.4
0.7	20.1
0.8	13.2
0.9	11.9
1.0	11.2

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Mr. Umair Shahzad was born in Faisalabad, Pakistan on 28th September, 1987. He has completed his M.Sc. Electrical

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He has worked at The University of Faisalabad, Faisalabad (Pakistan) as a LECTURER for two years. During this tenure, he has taught various subjects on Control and Power Engineering to B.Sc. Electrical Engineering students. On his outstanding teaching abilities, he was presented the Best Teacher Award in 2014. His research interests mainly consist of power systems, load flow studies, renewable energy and smart grids.

Mr. Shahzad is currently a member of Pakistan Engineering Council (PEC).