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Reactive power management by varying frequency of capacitor in renewable energy resources

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Abstract: Stability and active power sharing through Renewable energy Systems (RESs) are major concern; whereas reactive power control of RES is also important to increase the performance capacity of RESs. It is mainly through reactive power compensation in large grid connected renewable energy systems. The amount of the reactive power produced or absorbed by the wind farm and solar plants changes because of the power changes at different wind speed and sunlight. When the desired amount of reactive power needed by the system is not produced, the voltage sags and ultimately can collapse and disable the flow of power. For this reason, reactive power balance has to be carefully maintained to ensure an efficient operation. Various reactive power management sources such as capacitor banks, SVC, STATCOM, FACTS (Flexible AC-Transmission System) based on power electronics are used. In this paper a new concept of varying frequency of capacitor instead of varying value of capacitance is introduced. An automatic reactive power controller is designed for lagging and leading power factor which is very cost effective. Power factor correction techniques discussed in this paper have the capability of using in industries, households and power systems to make them stable and efficient. These techniques also improve voltage regulation of the system and reduce power system losses. Consumers can get rid of low power factor penalty by using these techniques.

Keywords: power factor, reactive power, renewable energy system

I. INTRODUCTION

In any country energy is a key element and basic building block. With the increasing time, demand of energy increases due to population growth, urbanization and modernization. The reserves of fossil fuels like oil, coal and gas are depleting day by day on which world energy has been relying on for so many decades. This is a cause of local, regional and global environmental concerns [1].

In order to meet increasing energy demands all the developing countries including Pakistan are focusing on utilization of renewable energy potentials. Research shows that after the oil crisis in the late seventies wind power industry started to flourish. Since then developments in wind turbine power plants make it the champion of all renewable energy resources [2]. Another renewable source of energy which is abundant, sustainable is the sun [3]. Photovoltaic power plants generate as much as hundreds of MWs of energy [4].

For cost effective solar energy efficient ways are developing to collect, store and utilize it. The solar power of 86,000 TW is reaching the earth's surface. In order to satisfy the global power consumption currently solar collectors provide solar power which covers 0.22% of our planet [3].

Due to large scale penetration of these renewables the reliability factor is an important parameter that needs to be considered because they can be a cause which affect the operation of power systems. These power plants can cause disturbances and fluctuations in power because they inject active power into the system and they depend on fluctuating natural resources. Due to variations in voltage these plants may cause voltage collapse. For these reasons adequate control of active and reactive power flow is needed to improve the performance of the system [4].

Reactive power is one of the major issues that the industries are facing now days. At present, KVAR capacity is changed required at the load end through parallel switching of capacitors in capacitor bank. On the other hand, if frequency is controlled (varied) at capacitor bank side via controller, then without taking capacitors in and out from the system at regular intervals; the reactance ($X_c = 1/2\pi fC$) is changed and thus KVAR capacity required at the load end is controlled. This method of controlling KVAR reduces the cost of additional capacitors required for parallel switching. Only series switching of capacitor is required in above proposed scheme to change voltage level if there is any change in voltage across capacitor bank, so that each capacitor will work in safe range.

II. REACTIVE POWER REQUIREMENT FOR WIND AND SOLAR PV

Previously conventionally using generating units are larger than variable generation plants. Variable generation plants either use those generators which do not have capability of voltage regulation, like induction generators (wind) or line-commutated inverters (PV). Synchronous generators have the ability to provide voltage regulation. There is a need to maintain reactive and voltage regulation to operate system properly because of vast generation of solar and wind. For this reason, asynchronous generators or full conversion machines having electronic interfaces are used in new wind plants which have enough capability of reactive power and voltage regulation. By adding shunt capacitors, STATCOM, SVC and other equipment the reactive power capability of solar and wind plants can be further improved [5] [6].

In solar photovoltaic reactive the size of inverter and real power output of solar panels are limiting factors of power. Inverters used for wind plants and solar PV can provide reactive capability at partial output, but converter need to handle full active and reactive currents at full power and for this they need to be sized larger for any inverter-based reactive capability [5][6].

Power converters are used in some types of wind generators and PV generators. Converters have different reactive capability than synchronous machines because synchronous machines are power limited, and converters has its limitations of temperature values, internal voltage, and current constraints. [5][6].

III. REACTIVE POWER MANAGEMENT

An important component of operating an alternating current (AC) electricity system is reactive power, and controls system voltage within ranges for effective and reliable operation of the transmission system. Sometimes for effective supply of electricity from generation to load, generators or other resources must either supply or consume reactive power for the transmission system to maintain voltage levels [13].

Reactive power management is defined as the control of voltages of generators, variable transformer taps settings and compensation. For the reduction of system losses and voltage control, shunt capacitor and reactor banks are allocated at appropriate positions.

Various techniques are implemented in power plants for reactive power compensation. A combination of controlled capacitors and inductors can be made mechanically switched on and off to provide a reactive power as a source. Flexible Alternating Current Transmission Systems (FACTS) are used to obtain a continuously variable reactive power source, they have a combination of capacitors and inductors to provide continuously variable leading or lagging reactive power. Static VAR Compensators (SVCs) and STATCOMs are the types of FACTS devices that are designed to provide voltage support. Other devices include Tap changing transformers, Thyristor controlled series capacitor (TCSC) Unified Power Flow Controller (UPFC), Static Synchronous Series Compensator (SSSC) [7].

IV. METHODOLOGY OF SIMULATIONS

In the method of frequency varying of capacitors the AC voltage is rectified to DC cause harmonic currents. As harmonic current increases it results in distortion of supply waveform and increase losses in the supply. By the addition of capacitors power factor correction cannot be achieved for distorted waveforms. The waveform can be back to its original undistorted state by means of power factor correction inverters. In the model proposed here inverter is used to change the frequency in order to achieve desired power factor.

A. Reactive Power Management for a Leading Load

The model shown in Fig. 1 consists of a leading power factor load. The inductor is connected across the inverter. The frequency of system remains same at 50Hz but frequency of inductor varies by inverter to achieve the desired power factor. In this way reactive power is controlled. The power factor of load is leading so frequency of inductor varies to make the power factor lagging. Inside inverter controller is programmed on the basis of different power factor and switches on or off pulse generators of different frequency.

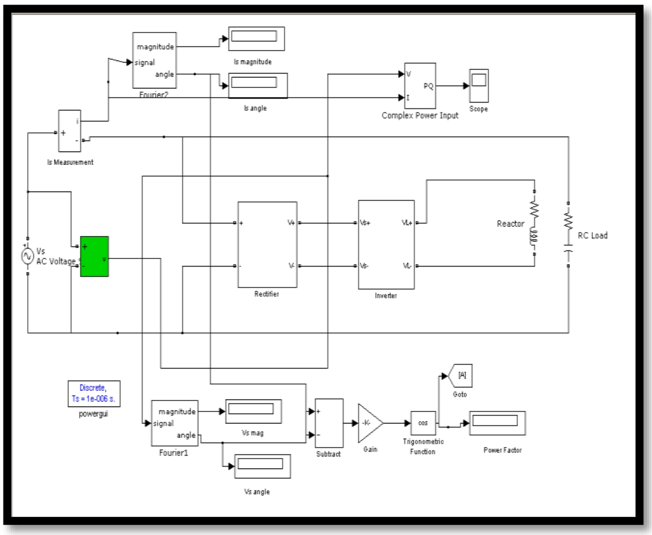

Fig. 1 MATLAB/Simulink Model consist of inverter for a leading PF load

B. Reactive Power Management for a Lagging Load

The model shown in Fig. 2 consists of a lagging power factor load. The capacitor is connected across the inverter. The frequency of system remains same at 50Hz but frequency of capacitor varies by inverter to achieve the desired power factor. In this way reactive power is controlled. The power factor of load is lagging so frequency of capacitor varies to make the power factor leading. Inside inverter controller is programmed on the basis of different power factor and switches on or off pulse generators.

C. Algorithm and flow chart

The algorithm is used to develop the computer program for microcontroller to determine the values of power factor for a given load.

The controller continuosly checks for the power factor values on different load values and ultimately gives signal to pulse genearotor.Pulse generators used are of different frequencies which in turn changes the frequency of either inductor or capacitor and improves power factor. The flow chart of algorithm used in given in Fig. 3

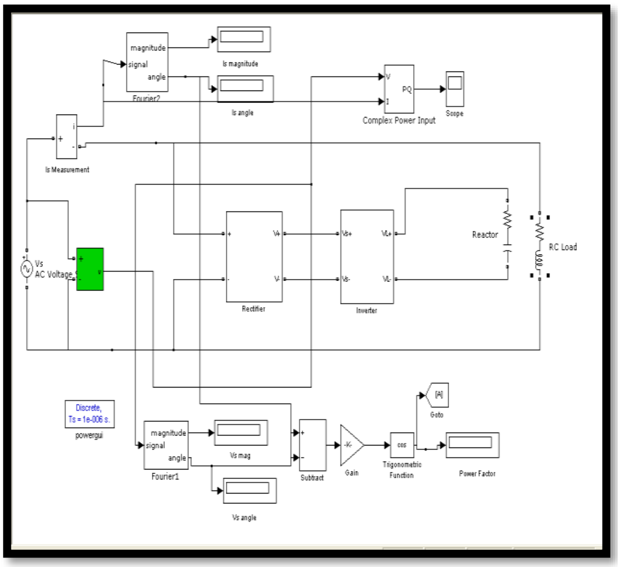

Fig. 2 MATLAB/Simulink Model consist of inverter for lagging PF load

V. RESULTS OF SIMULATIONS

The measurements are taken by changing the load values shown in Table 1 and 2. For a leading load when power factor is 0.447 the pulse generator switched on having frequency 124 Hz and power factor becomes 0. 95. For a lagging power factor load when power factor is 0.447 the pulse generator switched on having frequency 204.2 Hz and power factor becomes 0.85.

From the observations of Table 1 and 2 it can be concluded that for a leading load the frequency of inductor needed to increase if load is increased. While for a lagging load frequency of capacitor needed to decrease if load is increased. In this way reactive power demand at the load end is maintained by keeping system frequency constant.

Table 1 Observations for a lagging power factor load

Resistance ohms	Inductance (H)	Lagging power factor	Capacitance (mF)	Frequency of capacitor	Leading power factor
2	0.013	0.447	1	204.2	0.85
4	0.03	0.371	1	98.1	0.95
6	0.095	0.196	1	60.1	0.98

Table 2 Observations for a leading power factor load

Resistance ohms	Capacitance (uF)	Leading power factor	Inductance	Frequency of inductor	Lagging power factor
2	795	0.447	0.001	124	0.95
4	318	0.371	0.001	258	0.9
6	106	0.196	0.001	421	0.9

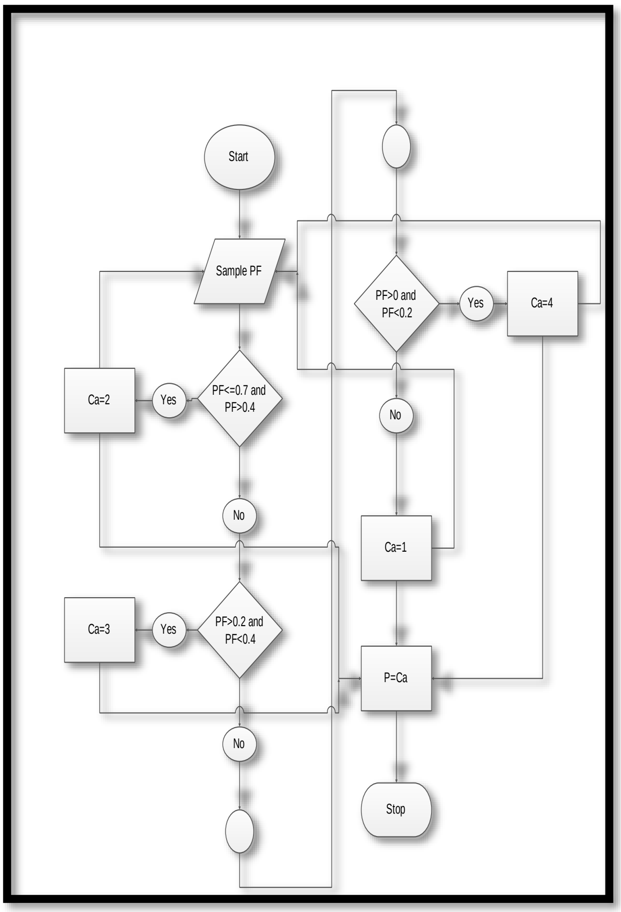

Fig. 3 Flow chart of program for a leading load

VI. CONCLUSION

It can be concluded that traditionally by using capacitors, power factor is improved. If reactive load is increased then more capacitors are used to improve power factor. The new method introduced in this paper is by varying frequency of either inductor or capacitor reactive power is controlled. This proposed technique provides major benefits to consumers, manufacturers as well as to the utility. The benefits include cost savings in capacitor banks, cost savings in reactive power controller, easy maintenance, flexibility in production of value of capacitor. Utility will be able to operate its generators with improved power factor to produce more shares of active power in given MVA or KVA ratings. Reactive power controlling through this scheme helps the utility to achieve the balance between the demand and supply in effective manner.

VII. FUTURE WORK

It can be concluded that power factor correction techniques have the capability to be applied to households, power systems and industries which makes them stable and efficient. In this way stability and efficiency of the system and apparatus increases. The use of microcontroller in the project reduces the cost. Multiple parameters can be controlled using microcontroller and the cost of using extra hardware such as timer, input output ports, RAM and ROM reduces.

Integration of Wind & PV Generators in the grid severely affects the voltage stability of power system, therefore reactive power controlling must be done for these cases to ensure better voltage regulation & improved power factor.

Power Factor correction techniques must be applied in industries, power system & households to make them stable and efficient.

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