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Research Article

Power Quality Enhancement by PI Controller based RLC with Particle Swarm Optimization using STATCOM

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Abstract

The power quality resources have continuously played an important role in the growth of human livings. PSO tuned PI controller are compared and a mark reduction in total harmonic reduction is with number of generations .In our proposed scheme is to define the global and local best fitness for the STATCOM in order to improve power quality and minimize power losses in the grid with PI controller and RLC branch, using Particle Swarm Optimization algorithm and we also comparing with base Genetic algorithm which implement programming and Simulink design in MATLAB tool.

Keywords: *Electric power quality, PI Controller, RLC, Power losses, STATCOM, Particle swarm optimization, Jacobian, GA (genetic algorithm) etc.*

1. Introduction

A Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure or disoperation of end user equipment's. Utility distribution networks, sensitive industrial loads and critical commercial operations suffer from various types of outages and service interruptions which can cost significant financial losses.

This dissertation is dedicated to a comprehensive study of static synchronous compensator (STATCOM) systems utilizing cascaded-multilevel converters (CMCs). Among flexible AC transmission system (FACTS) controllers, the STATCOM has shown feasibility in terms of cost effectiveness in a wide range of problem solving abilities from transmission to distribution levels. Voltage swells are not as important as voltage sags because they are less common in distribution systems. Voltage dips are one of the most occurring power quality problems. Off course, for an industry an outage is worse, than a voltage dip, but voltage dips occur more often and cause severe problems and economical losses.

Particle Swarm Optimization: Particle Swarm Optimization (PSO) is an optimization method based on the principles of natural selection and genetics. This method can look for more solutions simultaneously. PSO generates random initial particles in the first step and then it applies velocity vectors to update the particles until a process stop condition is satisfied. It requires the test function calculation to determine how a reached solution is good D. Shirmohammadi, B. Wollenberg.1998.

Utilities often focus on disturbances from end-user equipment as the main power quality problems. This is correct for many disturbances, flicker, harmonics, etc., but voltage dips mainly have their origin in the higher voltage levels. Faults due to lightning, is one of the most common causes to voltage dips on overhead lines. The vector x contains the dependent variables including bus voltage magnitudes and phase angles and the reactive power output of generators designed for bus voltage control.

Genetic Optimization: We comparing with determine the D-STATCOM as an optimal system. Also, GA is an effective method in bulky and extended places that has coded variables so that led to the optimal solution T. An, M.T. Powell, H.L. Thanawala and N. Jenkins (2012). The advantage of coded variables is that the code is the ability to transform a continuous space to a discrete space. We use the GA method optimization in population or a set of points in a certain moment while the old method optimized has been applied for only point. This means that the large number of projects can be processed at a same time by GA and also it is notable that, GA method is based on directed randomness. In order to use of GA many concepts such as defined the objective function or cost function, definition and implementation of genetic space and definition and implementation of GA operators.

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The vector x also includes fixed parameters, such as reference bus angles, uncontrolled active and reactive powers for generators and loads, fixed impedances, line parameters, etc. The active power losses minimization is usually required when cost minimization is the main goal. The STATic synchronous COM pensator (STATCOM) is a shunt FACTS device and it was introduced and developed in the last decade. It is used to regulate voltage values at different points in the transmission lines.

2. Power Quality Formation with STATCOM

In Voltage Source Inverter including coupling transformer leakage resistance, Lp represents the coupling transformer leakage inductance. A Voltage Source Inverter is the core element of the STATCOM.it generates a balanced and controlled three phase voltage Vp. Rs+jωLs represents the source impedance whereas Rt+jωLt represents the line impedance.

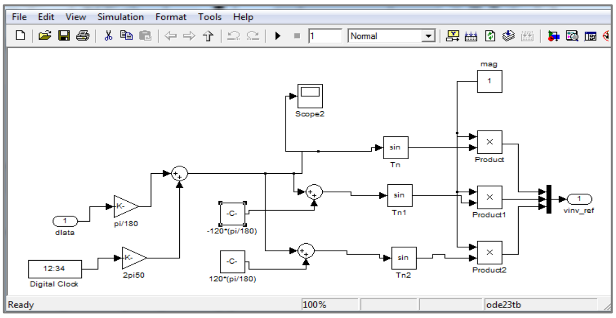

Figure 1: Subsystem block for phase voltage in different product

3. System Model

In our system model Power quality is a set of electrical boundaries that allow a piece of equipment to function in its intended manner without significant loss of performance or life expectancy. This definition embraces two things that we demand from an electrical device which are performance and life expectancy

Voltage Sag (Or Dip): A decrease of the normal voltage level between 10 and 90% of the nominal rms Voltage at the power frequency, for durations of 0. 5 cycle to 1 minute by cause of Faults in consumer's installation Faults on the transmission or distribution network Most of the times faults occur on parallel feeders.

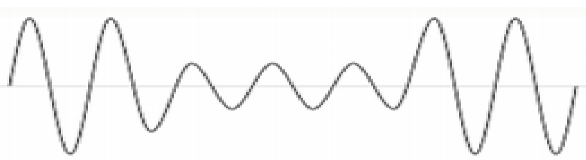

Figure 3.1: Voltage Sag

Voltage Swell

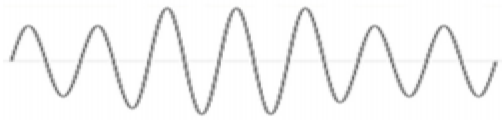

Figure 3.2: Voltage Swell

Momentary increase of the voltage, at the power frequency, outside the normal tolerances, with duration of more than one cycle and typically less than a few seconds by the cause of Start/stop of heavy loads, badly dimensioned power sources and badly regulated transformers (mainly during off-peak hours).

Harmonic Distortion: Voltage or current waveforms assume non-sinusoidal shape. The waveform corresponds to the sum of different sine-waves with different magnitude and phase, having frequencies that are multiples of power-system frequency. Cause of classic sources electric machines working above the knee of the magnetization curve (magnetic saturation), arc furnaces, welding machines, rectifiers, and DC brush motors.

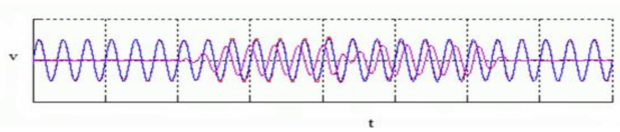

Figure 3.3 Harmonic Distortion

PI controller: A PI-Lead controller is a proportional gain in parallel with an integrator; both in series with a lead controller. The proportional gain provides fast error response. The integrator drives the system to a 0 steady-state error. PI controller is one of the most widely sought after controller in industry as it is the simplest to design. The overview of PI controller is given below:

Proportional (Gain) 'P' is Proportional control in which the output varies based on how far you are from your target. The error is multiplied by a negative (for reverse action) proportional constant P, and added to the current output. P represents the band over which a controller's output is proportional to the error of the system. E.g. for a heater, a controller with a proportional band of 10 deg C and a set point of 100 deg C would have an output of 100% up to 90 deg C, 50% at 95 Deg C and 10% at 99 deg C. If the temperature overshoots the set point value, the heating power would be cut back further. Proportional only control can provide a stable process temperature but there will always be an error between the required set point and the actual process temperature.

Integral (Reset) 'I' is an Integral control in which the output varies based on how long it's taking you to get to your target. The error is integrated (averaged) over a period of time, and then multiplied by 31 a constant 'I', and added to the current control output. 'I' represent the steady state error of the system and will remove set point / measured value errors. For many applications Proportional + Integral control will be satisfactory with good stability and at the desired set point.

Simulink Design

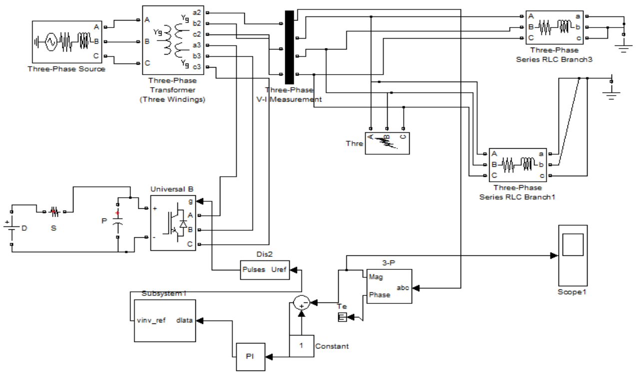

Figure 3.4: Simulink Model

The modeled system has been tested on different fault conditions with linear as well as non-linear load. The system is employed with three phase generation source with configuration of 25KV, 50 Hz. The source is feeding two transmission lines through a three phase, three windings transformer with power rating 250MVA, 50 Hz.
Winding 1: V1rms (ph-ph) = 25 KV, R1 = .002 (pu), L1 = .08002 (pu).
Winding 2: V2rms (ph-ph) = 11 KV, R2 = .002 (pu), L2 = .08002 (pu).
Winding 3: V3rms (ph-ph) = 11 KV, R3 = .002 (pu), L3 = .08002 (pu)

Table 3.1: Simulation Table for Discrete PI Controller

Discrete PI Controller (mask) (link)

This block implements a discrete PI controller.

Parameters

Parameter	Value
Proportional gain (Kp):	0.5
Integral gain (Ki):	500
Output limits: [Upper Lower]	[1e6 -1e6]
Output initial value:	0
Sample time:	50e-6

Check for an error space that changes with respect to time/iteration and the threshold value that determines dynamic environment if the value of gbest changes more than some threshold value for the same location.

4. Simulation Result

The variants of the problems are numerous which model the objective and the constraints in different ways. The basic OPF problem can described mathematically as a minimization of problem of minimizing the total fuel cost of all committed plants subject to the constraints.

$$Minimize \sum_{i=1}^{n} F_i(P_i) \tag{A1}$$

F(P_i) is the fuel cost equation of the 'i'th plant. It is the variation of fuel cost ($ or Rs) with generated power (MW).Normally it is expressed as continuous quadratic equation.

$$F_i(P_i) = a_i P_i^2 + b_i P_i + c_i, \quad P_i^{\min} \le P_i \le P_i^{\max} \tag{A2}$$

The total generation should meet the total demand and transmission loss. The transmission loss can be determined from power flow.

$$\sum_{i=1}^{n} P_i = D + P_l \tag{A3}$$

$$P_i = real(\sum_{j}^{n} V_i Y_{ij}^{*} V_j), i = 1,2,..n \tag{A4}$$

$$Q_i = imag(\sum_{j}^{n} V_i Y_{ij}^{*} V_j), i = 1,2,..n \tag{A5}$$

$$\mathbf{V_i^{min} \le Vi \le V_i^{max}} \quad \text{s} \tag{A6}$$

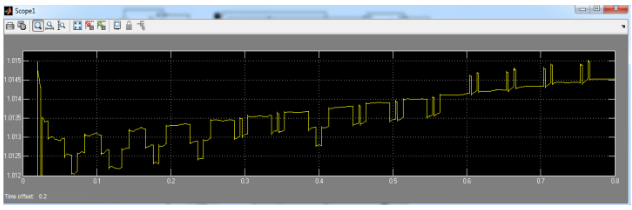

Figure 4.1: Simulation power quality improvement wrt time offset

$$\mathbf{LF_{ij} \le \text{Line flow limits}} \tag{A7}$$

The fault is created for the duration of 0.3s to 0.5s. The output wave for the load current with compensation and without compensation. In second case considered fault for both the feeders is double line to ground fault. For this fault resistance and ground resistance is 0.001ohm and 0.001ohm respectively. And the time duration for this fault is 0.3seconds to 0.5seconds. The fault is created for the duration of 0.3s to 0.5s. And fault resistance and ground resistance is 0.001ohm and 0.001ohm respectively. In this case a Double line to ground fault is considered for both the feeders. Here the fault resistance is 0.001 ohm and the ground resistance is 0.001 ohm. The fault is created for the duration of 0.2s to 0.6s.

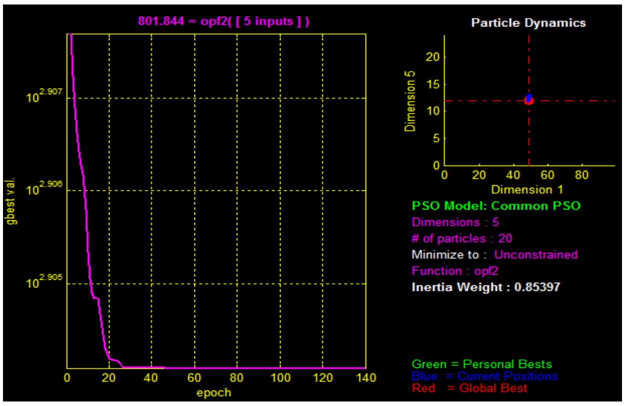

Figure 4.2: gbest value with best fitness in voltage regulation and improving weight inertia

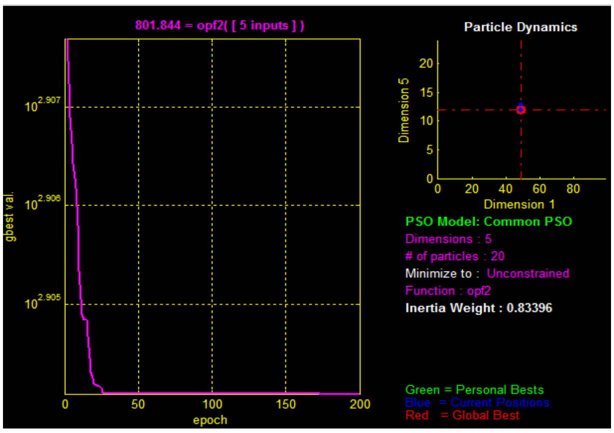

Figure 4.3 Final Improved weight with maximum coverage of voltage

1. Collect the busdata, line data and cost coefficients and their limits.
2. Convert the constrained optimization problem as an unconstrained problem by penalty function method.

Minimize

$$\sum_{i=1}^{n} F_i(P_i) + 1000 * abs(\sum_{i=1}^{n} P_i - D - P_l)$$

3. The epoch which returns the fuel cost, voltage, Generation, and transmission loss is the power flow routine and i am using the PSO I

PSO: 1/200 iterations, GBest = 805.09421750869865.
PSO: 20/200 iterations, GBest = 801.89517133289905.
PSO: 40/200 iterations, GBest = 801.8464175672442.
PSO: 60/200 iterations, GBest = 801.84469120207154.
PSO: 80/200 iterations, GBest = 801.84467976564179.
PSO: 100/200 iterations, GBest = 801.84429254788665.
PSO: 120/200 iterations, GBest = 801.84429254788665.
PSO: 140/200 iterations, GBest = 801.84408955604454.
PSO: 160/200 iterations, GBest = 801.84408955604454.
PSO: 180/200 iterations, GBest = 801.84398077869128.
PSO: 200/200 iterations, GBest = 801.84371808961077.
P1 = 48.8556 21.5005 21.6274 12.1322 12.0000
F1 = 801.8437
P = 176.6549 48.8556 21.5005 21.6274 12.1322 12.0000
TL = 9.3706
PSO: 300/500 iterations, GBest = 801.84360962771177.
PSO: 320/500 iterations, GBest = 801.84360962771177.
PSO: 340/500 iterations, GBest = 801.8436072032963.
PSO: 360/500 iterations, GBest = 801.84360514484456.
PSO: 380/500 iterations, GBest = 801.84360448001792.
PSO: 400/500 iterations, GBest = 801.84359710531487.
PSO: 420/500 iterations, GBest = 801.84359678791236.
PSO: 440/500 iterations, GBest = 801.84359678056865.
PSO: 460/500 iterations, GBest = 801.84359602650181.
PSO: 480/500 iterations, GBest = 801.84359599520189.
PSO: 500/500 iterations, GBest = 801.84359596776767.
P1 = 48.830710456655801 21.473756009580281 21.645864276661513 12.09437734657796 12.000000000000000
TL = 9.3761335733332481

Conclusion

Test system is analyzed and results are presented in the previous chapter. The results give the satisfactory applications of DSTATCOM in the distribution networks under different fault conditions and it can be concluded that DSTATCOM effectively improves the power quality in distribution networks with static linear. The values of the DC link capacitor and battery source were optimized using the PSO and the simulations results were compared with that of the system without compensation and with STATCOM, under both optimized and un-optimized conditions.

Future Scope In this thesis work it is shown that DSTATCOM can compensate harmonics in current. The work can be expanded in the following area: 1. Other advanced controllers like fuzzy controller, adaptive fuzzy controller can be employed with DSTATCOM to increase the effectiveness of DSTATCOM in distribution networks. 2. Dynamic loads can be considered in future work and the effect of DSTATCOM with them can be studied.

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