

Synchronization of Reactive Power in Solar Based DG and Voltage Regulated Elements Using Stochastic Optimization Technique

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Abstract: As the distribution generation (DG) based on the solar has attained more prominence and are broadly utilized by multitudes of client and the manufacturers of power on distribution system that is radial. The solar based distributed generation for the radial distribution system affects the changeover functions of the tap changers that are less laden as well as the capacitors connected in shunt and further causes loss of power. The paper attempts in developing an innovative process of synchronization using the stochastic optimization technique the particle swarm optimization to bring together the reactive power of the distribute generation of the solar and the elements that are regulated using the voltage. The synchronization is performed by predicting the load. The procedure for the performing the synchronization is framed on the operational cost and the cost of power loss as multi-objective function. The methodology followed in the paper is examined in the MATLAB over 10 kV, sixteen buses. The observed results were compared with the traditional methodologies to determine the efficacy eluding any failures in the conditions of the GRID.

Keywords: Distributed Generation, Solar Energy, Radial Distribution System, Voltage Regulated Elements, Stochastic Optimization Technique

1. Introduction

The role of distributed generation (DGs) nowadays on radial lines have increased in order to preserve voltage contained by the boundaries and also to diminish the losses of the radial grid The DG,s further are categorized into to non-dispatch-able and dispatch-able. The energy production based on the cost free inputs such as the wind and the solar comes under the category of the non-dispatch-able. The distributed generations based on the solar penetrate the distribution lines that are radial and disturbs the life expectancy of the elements that are voltage regulated by scaling up the operation of switching. This greatly influences the operations of the less burdened tap changers and the capacitors connected in parallel. The remedy put forth in the previous method for the losses, utilized the SCADA and the dynamic programming to regulate as well as synchronize the distributed generation and the devices regulated with the voltage. Moreover techniques utilizing integrated voltages were also used to synchronize the aforementioned. The above

mentioned methodologies however achieved convincing solutions without taking into consideration the reactive power impacts of the distributed generations.

The reactive power of the less laden tap changer and the capacitors connected in shunt was synchronized with the synchronous machines. The reduction in the loss of power was achieved using a best power flow method. The method proffered by a researcher utilized the trust region based sequential quadratic programming to reduce the distribution system active power loss and diminish the switching counts retaining the voltage in grid. This process was put forth by the author Sheng, et al [1] by incorporating the trust region sequential quadratic programming with the bound and the branch strategy to repeatedly estimate the optimization along with the trust region guidance. The system was further evaluated based on the demonstration of the proposed method over the IEEE 13 bus, the method clubbed the two different forms of generators synchronous and asynchronous with the elements that were voltage regulated and achieved the co-ordination in the reactive power utilizing the voltage regulation procedures. Whereas author Li, et al [2] in his paper proposed an “adaptive voltage control method” to energetically alter regulator parameters to fix device variations. Hypothetical research illustrates that the dynamic regulating parameters are framed accordingly such that the “adaptive control process” is hypothetically strong. The mechanism proved to be more compatible for the wide range of utility application.

Hatipoglu, et al The fundamental purpose of this paper is to provide with the development and simulation of a new technique for dynamic voltage stability management, focusing on in effect regulator and management of reactive power generation properties available in a micro grid environment [3] Kim, et al [4] “the novel method put forth does a in which the outcome of the distributed generation is transmitted supportively to the operations of the tap changer with the under load and capacitors connected in shunt, the methodology scopes at reducing the number of switching system operations and at reducing the power loss in the distribution lines while maintaining the grid voltage within the permitted range.” Jiayi, Huang et al [5] elaborates the micro grid technology it operations and the concepts the lie as the core of the micro grid. He further lists out the technology used in the distributed energy resources such as the diesel engines, fuel cells, small wind turbines, micro turbines, PV etc.

Kumar, et al [6] examines the procedures to minimize the transmission loss incurred when the wind turbine and the hybrid PV are integrated, the method utilizes the beta and the Weibull distribution and has developed a probabilistic frame work as a solution. Gaing et al [7] proposes method to solve the economic dispatch problem using the particle swarm optimization. Manikandan, R., et al [8] has performed the analysis of proportional integral derivative controller for regulating the speed of the electric motor engaged the industrial applications. Krishnaraj, N., et al [9] conducted "A Multihoming ACO-MDV Routing for Maximum Power Efficiency in an IoT Environment." Raj, Jennifer S et al [10] elaborates the "A Comprehensive Survey on the Computational Intelligence Techniques and Its Applications." Joseph, S. Iwin et al [11] presents the "Survey of data mining algorithms for intelligent computing system."

Sankaraiah, M., S et al [12] demonstrated the use of stochastic optimization technique in developing a harmonization in the reactive power between the distributed generation and the device that is regulated using the voltage, but the methodology followed gives more importance for the distributed generation that are dispatch-able than the non –dispatch-able.

So the paper puts forth as novel method using the PSO to frame a synchronization in the reactive power between the solar based distributed generation and the components regulated using the voltage. The paper mainly scopes to minimize the power loss and the switching operations and is formed as a multi-objective problem on the operational and power loss cost.

The method is formulated with the system model explaining the power generation of the solar unit in section 2. Problem Statement in the section 3. The synchronization using the particle swarm optimization in section 4 and performance analysis in section 5 conclusion in section 6.

2. The Solar Power Generation Modelling

The energy dissipated from the solar system relies on numerous aspects such as the properties of the materials, the temperature and the radiation circumstances, the locality where the solar units are equipped, etc. the equation.1 below describes the energy produced by the solar unit.

$$Eff_m = SC_{eff} (1 - \gamma(C_{temp} - S_{temp})) + \delta X \log S_{ir} \tag{1}$$

Where the Eff_m is the module efficiency, SC_{eff} is the solar cell efficiency, γ is the Temperature-Power Coefficient of SC , C_{temp} and S_{temp} are the temperature of the SC and the standard temperature respectively δ is the coefficient of irradiation and the solar irradiation is represented using the S_{ir} .

$$P_G = \frac{S_{ir}}{1000 \frac{w}{m^2}} X N_{pow} X (1 - \gamma(C_{temp} - S_{temp})) \tag{2}$$

While P_G and the N_{pow} indicates the generated power and the normal power of the SC respectively, the $\frac{w}{m^2}$ represents the units watts and meters.

3. Problem Statement

The figure.1 below depicts the connections between the solar unit linked with the grid via transformer as well as the transmission line.

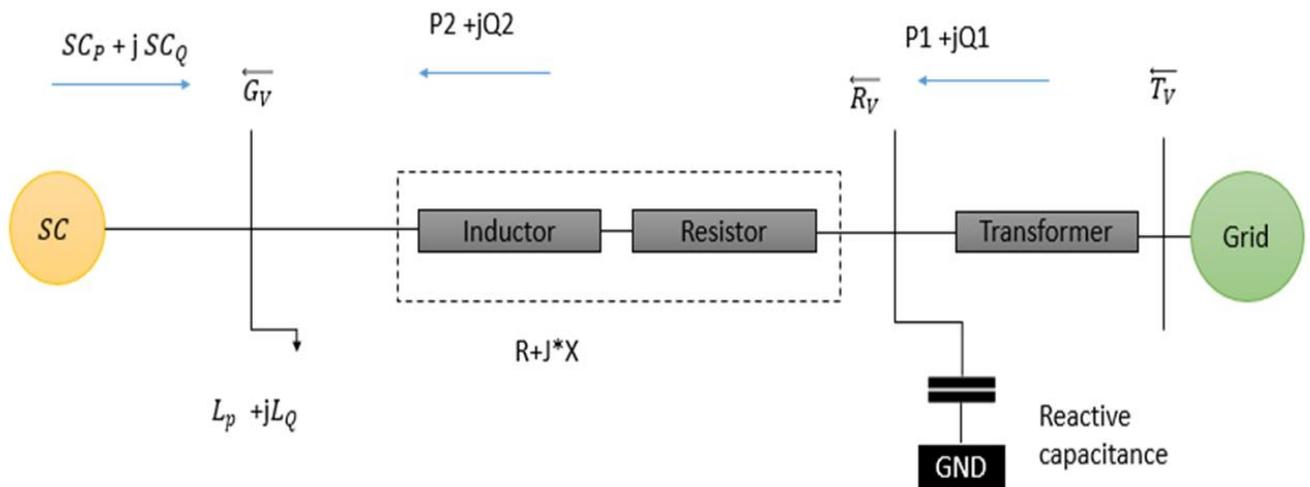


Figure.1 Connection Established Between Solar and Grid

The voltages of the transmitting end, receiving end and the grid is denoted using the T_V, R_V, G_V respectively.

The ‘P’ and ‘Q’ denotes the real and the reactive powers correspondingly, whereas the load and the capacitance of the transmitting end, receiving end and the grid is denoted as T_L, R_L, G_L and T_C, R_C, G_C correspondingly. The SC ‘P’ and ‘Q’ are denoted as SC_P and SC_Q correspondingly. The power loss (L_p) acquired is determined using the equation .3

$$L_p = I_{T_L}^2 X R_L \quad (3)$$

Where I_{T_L} the transmission is line current, and R_L denotes the resistance of the same. “The equality and the inequality restrictions in framing the multi-objective is listed below in the equation 4 and 5

$$\text{inequality constraints } \left\{ \begin{array}{l} SC_Q^{min} \leq SC_Q \leq SC_Q^{max} \\ |V^{min}| \leq |V| \leq |V^{max}| \\ |R^{min}| \leq |R| \leq |R^{max}| \\ C^{min} \leq C \leq C^{max} \end{array} \right\} \quad (4)$$

$$\text{equality Constraint } \left\{ \begin{array}{l} SC_P - L_p = LOSS_{realpow} \\ SC_Q - L_Q = LOSS_{reactivepow} \end{array} \right\} \quad (5)$$

4. Synchronization with PSO

PSO is a stochastic population based optimization technique, and very prominently use in optimizing the multiple objective functions. This method relies on the movement of the particle. The algorithm is also termed as the bird flocking algorithm as the method is based on the movement of swarms in search of food.

The steps below describes the general foraging behaviors of the swarms.

1. Swarms, initiate from a random position. (initial position recorded)
2. Randomly moves with the relative velocities. (initial velocity recorded)
3. Updates the position and velocity in each iteration.
4. Determines Pest and Gbest.
5. Re-orders the position based on the optimal values determined.

The outcomes of the iterations were utilized for optimizing the power loss and the tap changers, and capacitance connected in shunt the flowchart in figure.2 shows the step followed in the optimizing the parameters.

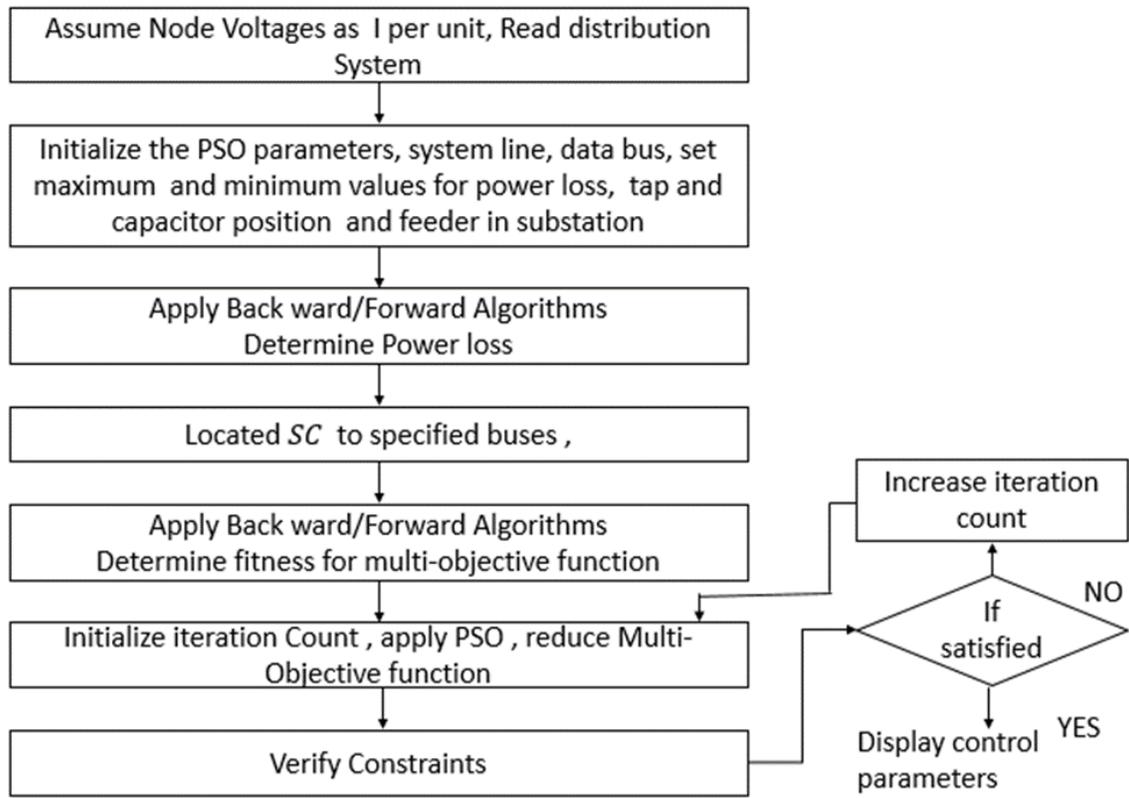


Figure.2 Parameter Optimization

5. Performance Analysis

The performance of the proposed method was validated using a real-world test kit, that had ten kilo volt sixteen buses and 3 feeders one 1.1 kilometer long, the other 1 kilometer long and the third one with 1.2 kilometer long. The capacitance was connected in parallel among the buses 1, 4, 9 and 13 and the ‘SC’ was connected to the buses 14, 5, 8 to validate its efficacy. The predicted load for every bus is tabulated below in table.1

Buses Load	Feeder 1 Active Load (MW)			Feeder 2 Active Load (MW)			Feeder 3 Active Load (MW)		
	5 hours	10 hours	20 hours	5 hours	10 hours	20 hours	5 hours	10 hours	20 hours
Bus 2	.65	1.9	1						
Bus 3	.5	2	.8						
Bus 4	.52	2.5	.9						
Bus 5	.54	2.3	1						
Bus 6				.62	2	1.2			
Bus 7				.63	2.8	1.4			
Bus 8				.65	2.8	1.5			
Bus 9				.52	3	1.6			
Bus 10				.55	2.2	2			
Bus 11							1.6	.6	1.9
Bus 12							1.4	.5	2.5
Bus 13							1.5	.4	2.4
Bus 14							1.7	.5	2.4

Table.1 Predicted Load

The figure.3 depicts the real world ten kilovolt system used in validating the proposed method.

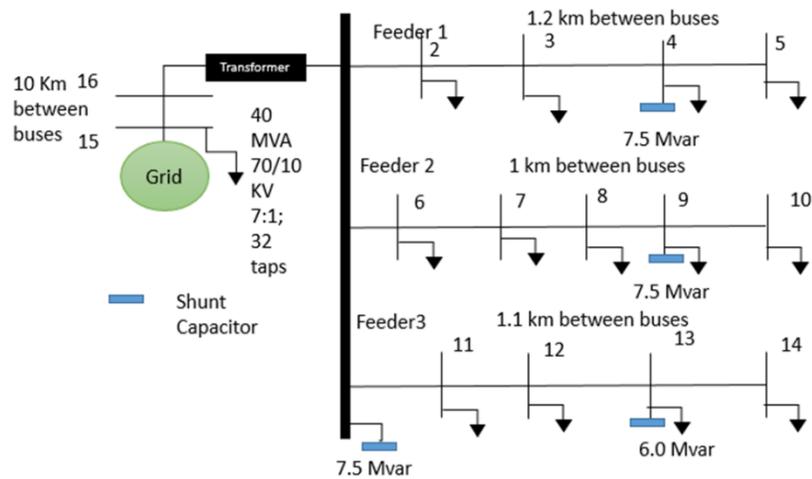


Figure.3 Real World Ten Kilovolt System

The table .2 below shows the results for the ‘SC’ positioned in the bus 14, 5 and 8 on the feeder 3, 2 and 1 respectively. The results observed on the power loss incurred switching operations of the devices that are voltage controlled are provided in table.2, the results obtained are compared with the traditional scheme to demonstrate the efficacy of the proposed.

Solar Cell position		Bus 5		Bus 8		Bus 14	
Regulating Methods		PSO	Traditional	PSO	Traditional	PSO	Traditional
Power loss (Mwah)		11.543	12.900	11.32	12.98	11.01	13.41
Switching Operations	Tap Changer	1	5	0	7	1	5
	Shunt Capacitor	0	10	9	10	1	11
	Shunt Capacitor at feeder 1	6	5	7	6	10	7
	Shunt Capacitor at feeder 2	3	4	4	4	3	4
	Shunt Capacitor at feeder 3	0	3	2	3	1	3

Table.2 Power Loss and Switching Operation

The figure.4 is the results observed on the cost of operations, the cost of the switching loss and the total loss in dollars. For the ‘SC’ positioned in the 14, 5 and 8. The cost spent on the proposed model is compared with the cost spent by the traditional method.

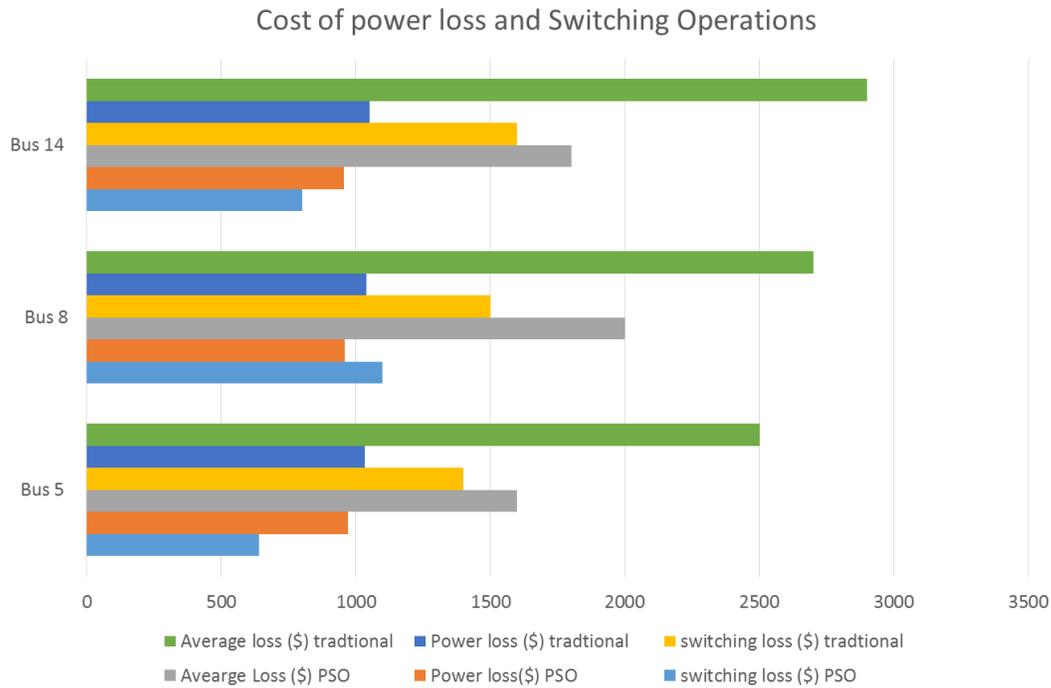


Figure.4 Cost Spent

6. Conclusion

The paper is the innovative measure of synchronizing the reactive power, of the distributed generation based on the solar units, and the voltage regulated equipment's, the proposed method was framed as a multi-objective problem and optimized using the particle swarm optimization. The procedure followed was validate with the real world system of ten kilovolt sixteen buses. The experiments proved that the proposed procedure had minimized the switching operations of the devices controlled using the voltage and has also diminished the losses in the power compared to the traditional method. The method proffered affords to offer an 8% reduction in loss of power, 60 % reduction in the switching loss than the traditional method.

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