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Allocation of UPQC using PSO for reactive power compensation in radial distribution networks: A Multi-objective planning

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ABSTRACT: This paper introduces a new concept of optimal utilization of a unified power quality conditioner (UPQC). The series inverter of UPQC is controlled to perform simultaneous 1) voltage sag/swell compensation and 2) load reactive power sharing with the shunt inverter. The active power control approach is used to compensate voltage sag/swell and is integrated with theory of power angle control (PAC) of UPQC to coordinate the load reactive power between the two inverters. Since the series inverter simultaneously delivers active and reactive powers, this concept is named as UPQC-S (S for complex power). A detailed mathematical analysis, to extend the PAC approach for UPQC-S, is presented in this paper. The performances of two MOPSO variants are compared and the better one is used in all subsequent studies. A load flow algorithm including the UPQC-PAC model is devised. The performance of the proposed algorithm is validate with case studies.

KEYWORDS: Multi-Objective Optimization, Power Distribution Planning, Reactive Power, Unified Power Quality Conditioner

I. INTRODUCTION

Reactive power compensation is an important issue in electric power systems, involving operational, economical and quality of service aspects. Consumer loads (residential, industrial, service sector, etc.) impose active and reactive power demand, depending on their characteristics. Active power is converted into “useful” energy, such as light or heat. Reactive power must be compensated to guarantee an efficient delivery of active power to loads, thus releasing system capacity, reducing system losses, and improving system power factor and bus voltage profile. Thus Optimal reactive power compensation can significantly improve the performance of a radial distribution network. There are several reactive power compensation strategies reported time-to-time in the literature, for example capacitor placement. The latest addition is the distribution FACTS (DFACTS) device allocation. Although DFACTS devices are traditionally used in power quality improvement they can be used in optimal reactive power compensation as well. In the optimal allocation of Capacitor is carried out to minimize network power loss and to improve node voltage magnitude. The unified power quality conditioner (UPQC) is one of the versatile DFACTS devices. The research on UPQC is mostly focused on the mitigation of power quality problems for single load. The theme of this paper is set as an investigation of its potential applicability in optimal reactive power compensation of a distribution network. The

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UPQC is a combination of series and shunt active filters connected in cascade via a common DC link capacitor. The main purpose of a UPQC is to compensate for supply voltage power quality issues such as sags, swells, unbalance, flicker, harmonics, and for load current power quality problems such as, harmonics, unbalance, reactive current and neutral current. With the two inverters, a UPQC can protect a customer/load from sag, swell in supply voltage, and it can also reduce the harmonic pollution created by the load. The shunt inverter injects a shunt compensating current to the load in order to provide load reactive compensation and to compensate the harmonic distortion created by the load. The series inverter is used to mitigate voltage-related problems, for example, sag and swell in supply voltage, etc. Basically, it injects a series voltage to the load. The series inverter only provides active power in UPQC-P and reactive power in UPQC-Q by injecting a controllable in-phase and a controllable quadrature voltage, respectively so as to mitigate voltage sag problem. The series inverter in UPQC-S can simultaneously provide both real and reactive powers. A modified design of the phase angle control model for UPQC (UPQC-PAC)[15] is proposed in this work. In the UPQC-PAC, the series inverter injects a controllable series voltage so as to shift the phase angle of the load voltage. Due to this phase shift, the series inverter participates in load-reactive power compensation along with the shunt inverter and helps in reduction of the VA rating of the shunt inverter. In UPQC is modelled for the reactive power compensation of a single load. Thus, its design is slightly modified so that a UPQC can be capable of providing the reactive power compensation of a distribution network. To determine the optimal location and parameters of UPQC, planning model is formulated with objective functions. They are minimization of: 1) network power loss 2) percentage of nodes with under voltage problem. The simultaneous optimization of these objectives is carried out using Pareto-dominance principle to obtain a set of non-dominated solutions called Pareto approximation set, in which no solution is inferior to other. The solution strategy used is particle swarm optimization (PSO) for its easy implementation, effective memory use, and an efficient maintenance of the solution diversity. Its performance is also tested on a number of power system problems. Since PSO is a multi-point search algorithm, it can provide a set of non-dominated solutions in a single run. Their performances on the present problem are compared and the better one is used in subsequent studies.

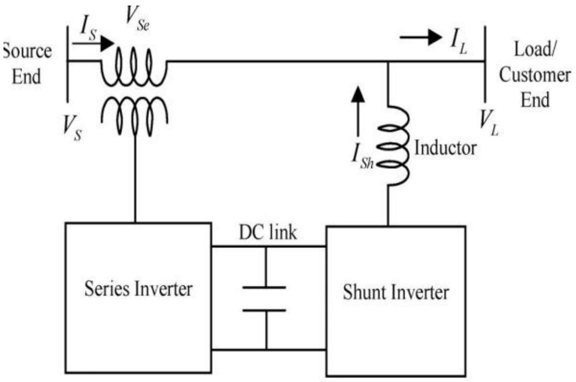

Fig. 1. Basic schematic of UPQC

II. LITERATURE REVIEW AND RELATED WORKS

During the present years, demand for power has been increasing drastically. But the power generation stations and transmission system expansion is limited severely due to the limited availability of resources. Distributed Generation became a research topic for the past twenty years. Lot of study is carried out in this area. Dugan, R.C. and McDermott, T.E. [1] defined the UPQC system as follows. Dispersed Generators that are interconnected to utility distribution systems will be smaller than 10MW. Generally larger units are directly connected to transmission facilities. The UPQC units installed in general will not be more than 1 or 2 MW and they are majorly installed by utility. This technique of generating power is called as

Dispersed Generation (In this UPQC)". In olden days, to increase the voltage profile capacitor banks are used in the network since 1997, FACTS devices widely used for static switching operation. Development of new UPQC topology/structure, for example,3-phase 4 wire structure , interline UPQC in which these two inverters are placed in different feeders of a network, and UPQC without the common DC link. Electrically, Radial distributed network are interconnected, reactive power compensation are required which is referred from [4] S. Deshmukh, B. Natarajan, and A. Pahwa, "Voltage/VAR control in distribution networks via reactive power injection through distributed generators," IEEE Trans. Smart Grid2012.

To overcome the problems in normal Radial distributed interconnected networks capacitor are placed in the network are referred from journal M. Chis, M. Salama, and S. Jayaram, "Capacitor placement in distribution systems using heuristic search strategies," Proc. Inst. Elect. Engineering in Generation.,
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In normal interconnected networks capacitor placemen tat minimum voltage is placed based on references from [1] D. Das, "Reactive power compensation for radial distribution networks using genetic algorithm," Int. J. Elect. Power Energy Syst., vol. 24, 2002.
Power quality has been improved by UPQC is from [11] D. O. Kisck, V. Navrapescu, and M. Kisck, "Single-phase unified power quality conditioner with optimum voltage angle injection for minimum VA requirement," in IEEE Proc. Power Electronics Specialists Conf., Bucharest, Romania.

III. EXISTING SYSTEM

In radial interconnected distributed system, voltage is not distributed equally to all the parts of entire system. Due to load changes on every time to time, normally loads are inductive or capacitive loads. Since reactive power are injected in to the system so the system needs compensation for to reduce reactive power. In olden days capacitor banks are utilized at the received end in distribution system. Now a day's static compensators are used i.e., D-STATCOM, UPQC etc. But in inter connection system very difficult to place a compensator at a particular place because of system loads. Real-time applications such as optimization of network, switching, estimation of the state, and so on, requires an efficient and standard power flow technique. Due to special features of distribution systems such as Radial structure, high ratio of R/X and wide-ranging reactance and resistance values. To optimize the inter connected system some techniques are used to find the minimum nodal voltage point.

IV. PROPOSED TECHNIQUE

Proposed Configuration of UPQC

In the proposed planning approach, a multi-objective planning model is formulated to determine the optimal location for UPQC, the optimal amount of reactive power compensation required at the location. These optimizing variables are determined by minimizing objective functions. They are 1) Network power loss 2) Voltage profile improvement 3) Percentage of nodes with under voltage problem. These objectives deals with the performance of network. The minimization of these objectives is required to obtain better performance a network.

Fig.2. Shows the configuration of proposed UPQC, which additionally has a DC/DC converter and super-capacitors for compensating the voltage interruption. The energy in the DC link charges the super capacitors through the bi-directional DC/DC converter when the system is in normal operation. The energy in the super-capacitors is released to the DC link through the bi-directional DC/DC converter when the voltage interruption occurs. The control system has three major elements which are shunt inverter control, series inverter control, and DC/DC converter control. When the level of source voltage is maintained as 1.0 p.u., the system works in normal mode. When the level is between 0.5 and 1.0 p.u. or higher than 1.0 p.u., the system works in voltage sag or swell mode. When the level is lower than 0.5 p.u., the system works in interruption mode. In normal mode, the series inverter injects the zero voltage and the shunt inverter absorbs the current harmonics generated by the load. The DC/DC converter works in charge mode or standby mode depending on the voltage level of the super-capacitors. In voltage sag or swell mode, the series inverter injects the compensating voltage to maintain the load voltage constant. The shunt inverter absorbs the current harmonics generated by the load and the DC/DC converter works in standby mode. In voltage interruption mode, the series inverter is disconnected from the line and the circuit breaker is opened to isolate the source side. The shunt inverter starts to work as an AC voltage source. The DC/DC converter works in discharge mode to supply the energy stored in the super capacitors to the load.

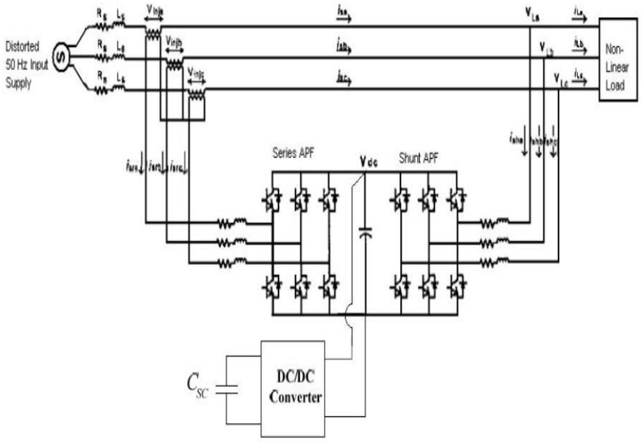
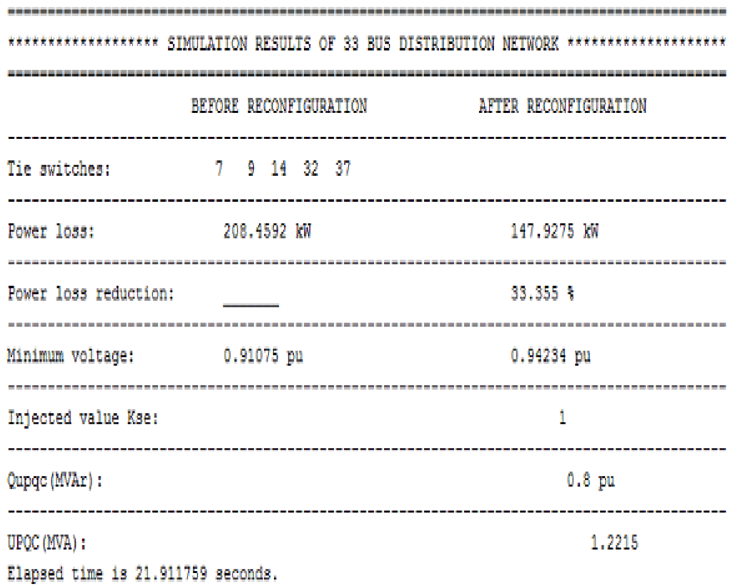


Fig.2. Configuration of proposed UPQC with energy storage.

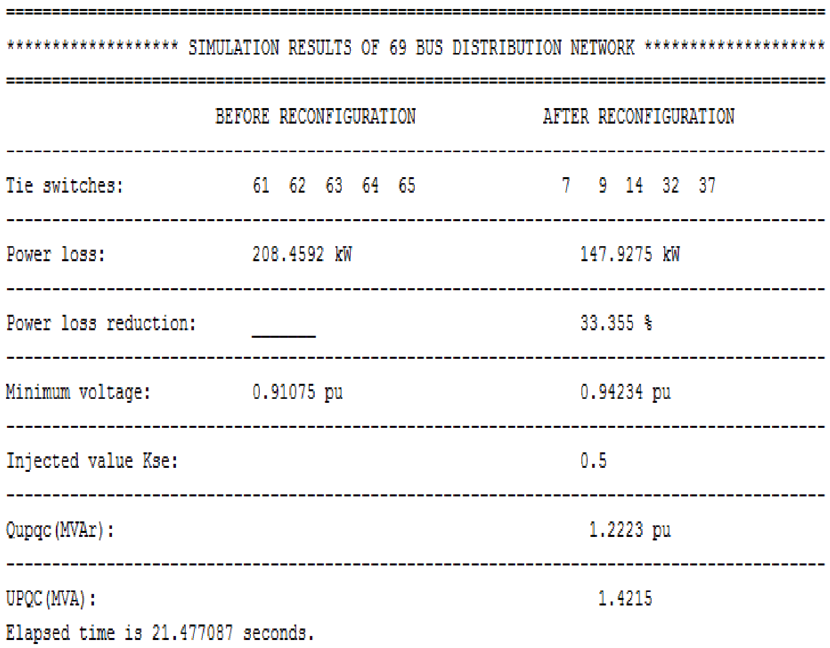
The control strategy for the series and shunt inverters of the proposed UPQC has been derived based on the Synchronous reference frame method (Hu and Chen, 2000). The series inverter control compensates the voltage disturbance in the source side due to the fault in the distribution line.

V. SIMULATION RESULTS



```
=========================================================================================
****************** SIMULATION RESULTS OF 33 BUS DISTRIBUTION NETWORK *******************
=========================================================================================
                        BEFORE RECONFIGURATION              AFTER RECONFIGURATION
-----------------------------------------------------------------------------------------
Tie switches:              7   9  14  32  37
-----------------------------------------------------------------------------------------
Power loss:                 208.4592 kW                         147.9275 kW
-----------------------------------------------------------------------------------------
Power loss reduction:       ______                              33.355 %
-----------------------------------------------------------------------------------------
Minimum voltage:            0.91075 pu                          0.94234 pu
-----------------------------------------------------------------------------------------
Injected value Kse:                                                   1
-----------------------------------------------------------------------------------------
Qupqc(MVAr):                                                          0.8 pu
-----------------------------------------------------------------------------------------
UPQC(MVA):                                                               1.2215
Elapsed time is 21.911759 seconds.
```

Fig.3. simulation result of 33 bus Distribution network:



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=========================================================================================
****************** SIMULATION RESULTS OF 69 BUS DISTRIBUTION NETWORK *******************
=========================================================================================
                      BEFORE RECONFIGURATION              AFTER RECONFIGURATION
-----------------------------------------------------------------------------------------
Tie switches:              61   62   63   64   65              7   9   14   32   37
-----------------------------------------------------------------------------------------
Power loss:                208.4592 kW                        147.9275 kW
-----------------------------------------------------------------------------------------
Power loss reduction:      ______                             33.355 %
-----------------------------------------------------------------------------------------
Minimum voltage:           0.91075 pu                         0.94234 pu
-----------------------------------------------------------------------------------------
Injected value Kse:                                           0.5
-----------------------------------------------------------------------------------------
Qupqc(MVAr):                                                   1.2223 pu
-----------------------------------------------------------------------------------------
UPQC(MVA):                                                      1.4215
Elapsed time is 21.477087 seconds.
```

Fig.4. simulation result of 66 bus Distribution network:

TABLE I
COMPARATIVE RESULTS OF REACTIVE POWER COMPENSATION WITH UPQC AND DSTATCOM

Operational aspects	UPQC allocation		DSTATCOM allocation	
	Solution A	solution B	Solution A	solution B
UPQC location	61	57	61	61
Power loss(kw)	149.7	196.77	158.61	221.04
Minimum Node voltage(p.u)	0.9401	0.958	0.9245	0.949
MVA	1.19	0.82	0.924	2.68

VI. CONCLUSION

A multi-objective planning for the reactive power compensation of radial distribution networks with UPQC allocation has reports that the allocation of UPQC on considered 33and 66 buses interconnected system. Traditionally, UPQC used in power improvement of single load and also reactive power compensation distributed systems UPQC with DC link converter suppress total harmonic distortion and compensates reactive power with optimal allocation. . at a specified location by using PSO technique, improves bus bar voltage profile, reduces the overall power loss, transient over voltage suppressions, power factor correction, low noise levels. Comparing with STATCOM, UPQC provides better results. Due to optimal location of UPQC increases voltage stability limit, line load ability, load balancing and improves the system stability. This needs for future investigations.

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