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LOAD SHEDDING PRIORITY AND ISLANDING BASED ON Q LEARNING FROM CONTOURLET COEFFICIENTS

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Abstract

We propose a new voltage control scheme for distribution networks based on a multi-agent system where the Unified Power Quality Conditioner (UPQC) shunt and series power transforming section is modified with OLTC. The power coupling stage to the transmission line via OLTC based tap selection detected by Q learning algrithm. The large voltage fluctuations caused by PV generations are effectively regulated by adjusting the conventional independent types of tap-changing controllers. It is expected to achieve an optimal control performance by developing a new optimal control law applicable to decentralized autonomous control. The proposed method is applicable to general distribution network and highly efficient for popular radial networks under certain approximations. The effectiveness of the proposed scheme is demonstrated through numerical simulations with hybrid grid setup. The proposed hybrid system can effectively suppress the voltage fluctuation along with hysteresis band reduction. The simulation of proposed work is carried out using MATLAB software.

INTRODUCTION

In modern power systems, distribution utilities mandate the connected loads compliance with the strict power-quality standards. This is to improve the reliability of the distribution system to cater the needs of critical loads and sensitive automation systems.

The major challenges to maintain good quality power are:

1) fundamental reactive power requirements of the connected loads;

2) voltage sags and swells at the point of common coupling (PCC) due to connection and disconnection of large industrial loads and reactive power compensating capacitors; and

3) voltage and/or current harmonic distortion due to the presence of nonlinear loads. Active power filters (APFs) are the most promising and widely used solutions for improving the power quality (PQ) at the distribution level [1], [2]. These APFs can be classified as shunt APF, series APF, and hybrid APF. The combination of both series and shunt APFs, to mitigate almost all of the voltage- and current-related PQ problems, is a unified power-quality conditioner (UPQC). Superior performance and the ability to mitigate almost all major PQ problems make UPQC the most attractive solution for PQ improvement despite its high cost, complex structure, and control [1]–[3]. The system configuration of a UPQC is shown Fig. 1. Current trends in the area of UPQC are directed toward operating the UPQC with minimum volt-ampere (VA) loading to reduce the overall system losses [3]–[12]. However, all of the reported work centered on minimizing the VA loading during voltage sag conditions [3], [4], [7]–[12]. The sizing aspect of the UPQC system (including the shunt inverter, series inverter, and series transformer) considering individual shunt and series inverter VA loadings under different operating conditions (such as steady state, voltage sag, voltage swell, and voltage and current harmonics compensation scenarios) is the main focus of this paper and has not been addressed and studied so far. Based on the control strategy being employed for voltage sag or swell compensation, the UPQC systems can be classified as UPQC-P, UPQC-Q, and UPQC-S. The UPQC-P is considered to be a conventional UPQC, where voltage sag and swell compensation are performed by injecting/absorbing the active power (in-phase or out-of-phase voltage) through the series part of the UPQC whereas the shunt inverter supports the load reactive power, active power required by the series inverter, and the losses in the system. For the same percentage of voltage sag and swell compensation, the VA loadings of series and shunt inverters will be maximum during the UPQC-P, compensating for the maximum voltage sag. Hence, UPQC-P should be designed based on the maximum voltage sag

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compensation. While in case of UPQC-Q the voltage injected through a series transformer is in quadrature with the source current. Thus, series inverter does not require any active power for compensating the voltage sag except for the switching and filtering losses. The UPQC-Q approach is limited to voltage sag compensation since it cannot compensate for the voltage swell. For the same amount of sag compensation, UPQC-Q requires larger series injection voltage magnitude compared to UPQC-P. This increases the VA rating of the series transformer significantly.

Generally, the voltage sags and swells are short duration PQ problems. Thus, in UPQC-P and UPQC-Q, series inverter VA loading will only be utilized for short durations. On the other hand, the shunt inverter VA loading is fully utilized throughout the operation, due to continuous load reactive power support and current harmonic compensation. To enhance the utilization of series part of UPQC during steady state, part of load reactive power is supported by the series inverter in UPQC-S. This role of series inverter not only improves its utilization, but also reduces the shunt inverter VA loading. Due to the load reactive power sharing feature of the series part, the rating of the shunt inverter in UPQC-S may be less than that in the UPQC-P. But this is at the expense of a slightly increased series transformer rating and reduction in the percentage of swell compensation capability.

Several methods have been proposed for the optimization of total instantaneous VA loading of UPQC (i.e., algebraic sum of VA loadings of shunt and series inverters). In [9] and [10], the authors have used an offline optimization method to compute the optimum angle (displacement angle between source and load voltages) that ensure the minimum instantaneous VA loading of UPQC for the given percentage of voltage sag and load power factor. An “80 80” matrix-based 2-D lookup table is computed and used for the control of the series inverter during the voltage disturbance (sag/swell) conditions.

This algorithm minimizes the total UPQC VA loading at any given operating condition; however, it does not consider the variation in individual VA loadings of series and shunt inverters under different operating conditions.

Along with the load power factor, load current, and percentage of voltage sag, the authors have included the allowable total harmonic distortions (THDs) of load voltage and source current as variables in the optimization problem. A particle swarm optimization (PSO)-based technique is used to compute the instantaneous optimum angle. However, its impact on VA ratings of series and shunt inverters, and series transformers is not considered.

After examining different techniques for minimizing the VA loading of UPQC, it is clear that all the techniques directly or indirectly control the displacement angle. The satisfactory results supporting minimum VA loading claims, at a particular operating point, are found in the literature. It should be noted that obtaining minimum UPQC VA loading at a certain condition (such as voltage sag) does not guarantee minimum VA ratings of the shunt inverter, series inverter, series transformer, and, thus, the overall UPQC system.

This project deals with the sizing of the UPQC system with minimum possible ratings of shunt and series inverters without compromising any of its compensation capabilities under different operating conditions. An algorithm is proposed to minimize the overall VA rating of UPQC which determines the corresponding displacement angle, fundamental VA ratings of series inverter, shunt inverter, and series transformer.

EXISTING SYSTEM

Classical power system dynamics models that focus on the generation control can be modified to also include the load-side control. However, these models do not consider the total disutilitiy of the consumers. The recently proposed paradigm of ubiquitous continuous fast acting distributed load modulation allows the loads to assess their requirements and the overall imbalance of the system and then choose their consumption patterns. As a matter of fact, the OLC theorems achieve an equilibrium that benefits both the utilities and their clients. In other words, the key question of OLC theorems is: “how to adjust controllable loads in the power system to rebalance power and regulate the system frequency, while minimizing the aggregated disutility of controllable loads?”. This key question has been formulated as an optimization problem (3), whose objective function includes two costs (4).

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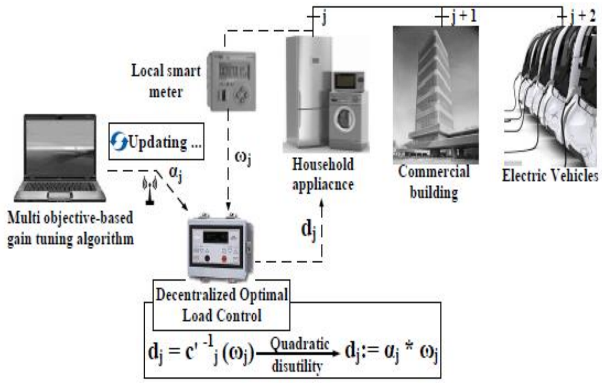

Fig. 1. Layout of Decentralized Improved Optimal Load Control Strategy.

Smart Grid

Smart Grid targets highly reliable, self-healing, self-regulating, demand response, efficient and cutting edge network that allows integration of high penetration of renewable energy sources. An illustration of smart grid scheme is presented in Fig. 1.

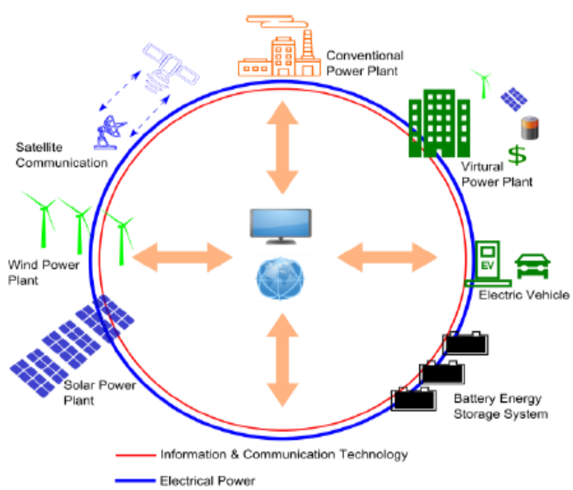

Fig 2 Smart grid general representation

A general definition follows the Electric Power Research Institute (EPRI) Smart Grid Resource Center, "A Smart Grid is one that incorporates information and communications technology into every aspect of electricity generation, delivery and consumption in order to minimize environmental impact, enhance markets, improve reliability and service, and reduce costs and improve efficiency." [58]. Therefore, the proposal will rely on these advanced information and communication technologies to perform adaptive and online coordination of DOCRs.

Impact of DG on Protective Overcurrent Relay

1) Coordination Loss:

The loss of coordination is defined as the violation of coordination time interval (CTI) constraint between the primary and backup relay [18,20,57].

Example: for a given fault at point F in Fig. 2, the coordination pairs to be analyzed in this scenario are R7-R8 and R7-R9 [primary-backup]. Due to the penetration of DG, these relays all sense an increase of short-circuit current. For R7, this is not critical as it is the primary relay. But for R8 and R9, their CTI with respect to R7 may not be fulfilled as when there was no presence of DG. Therefore, there is a loss of coordination between pairs R7-R8 and R7-R9.

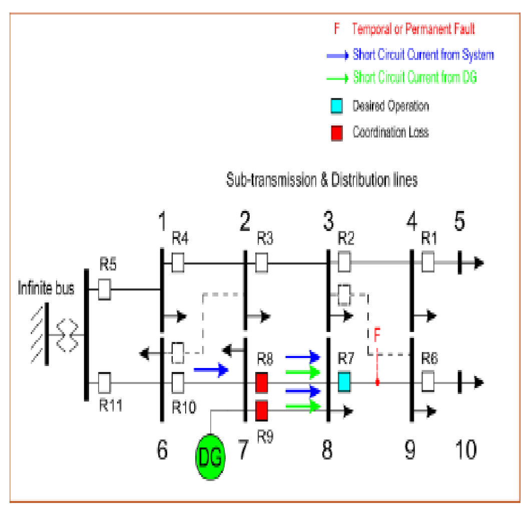

Fig .3 Loss of coordination due to DG penetration

A graphical illustration of coordination loss using inverse time relay characteristic curve for the coordination pair R7-R8 is presented in Fig.

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3. It can be clearly seen that after the integration of DG, the backup relay R8 accelerates its tripping time due to the increase of fault current; whereas the primary relay R7 is barely affected because its tripping time is already located at the horizontal asymptote curve. Hence, there is a loss of coordination because CTI is no longer preserved for the coordination pair R7-R8.

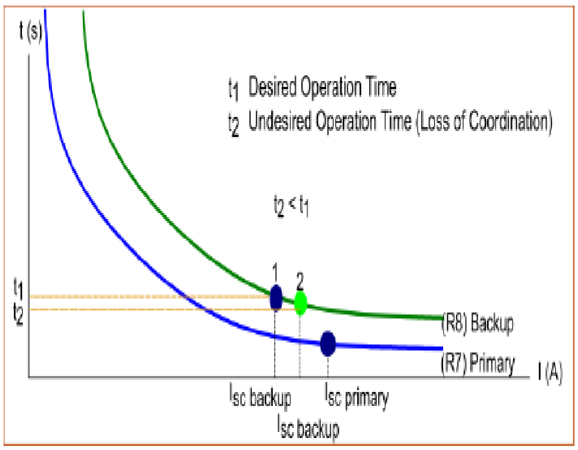

Fig .4 Illustration : Loss of coordination due to DG penetration

2) Islanding Operation:

The islanding operation is defined as the isolation of a certain part of a network from the main network due to dispatch or natural condition. For a given fault at point F in Fig. 4, suppose that relay R10 successfully cleared the permanent fault by tripping the circuit breaker. Then the remaining circuit from bus 7 to 10 will form an island operation network (micro-grid) fed by the DG (assuming that the DG has sufficient capacity to maintain stable operation for the islanded network). Under new network operating condition if a fault occurs at any point along the lines between buses 7 to 10; then both primary and backup relays will suffer significant time delay in clearing the fault due to the relatively small fault current contribution by the DG. The relays can regain their operation speed if they were re-adjusted/re-coordinated for this new network operation and topology.

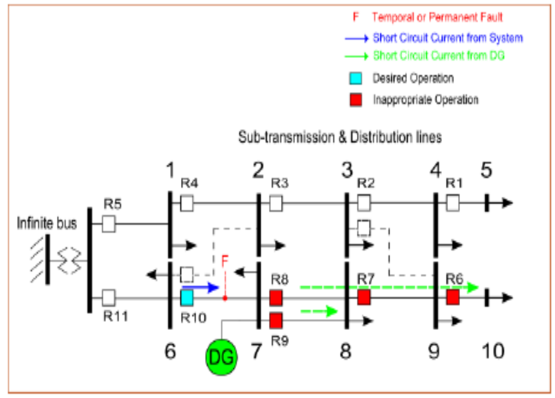

Fig. 5 Inappropriate relay delay operation

This can cause further problems such as load or source tripping. Many industrial motors have under-voltage tripping protection, so if the fault takes long time to clear then the voltage sag duration increases which may lead to a disconnection of industrial loads. The same applies to some power sources (ie: wind turbine generators), which disconnect from the network after several seconds for small sag or immediately after big sag.

A graphical illustration of an inappropriate relay delay operation using inverse time relay characteristic curve for the coordination pair R7-R8 is presented in Fig. 5. It can be clearly seen that after entering island operation mode, the backup relay R8 increases its tripping time due to the decrease of fault current; whereas the primary relay is barely affected because its tripping time is already located at the horizontal asymptote curve. Hence, there will be an undesired backup tripping time if a fault occurs during island operation mode.

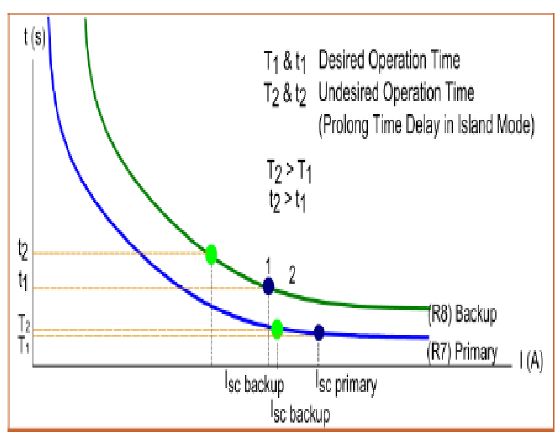

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Fig..6 Inappropriate relay delay operations

Detailed description of the adaptive protection scheme and the formulation of coordination problem are presented in the following sections.

A. Description of Adaptive Protection Scheme

The adaptive protection scheme for coordination of DOCRs including DGs is presented in Fig. 6. The proposed idea for mitigating the impacts of DGs on DOCR coordination is based on a centralized adaptive scheme. This protection scheme consists of a centralized processing server which analyzes and optimizes the data obtained through SCADA system of the network that implements overcurrent protection principle. The SCADA system monitors the network condition and identifies the operational and topological changes of the network. As soon as a change in the network is identified, the latest breaker and network configuration and/or the status of DGs are input into the centralized processing server. Based on the network status data, the server performs load flow, fault, contingency and sensitivity analysis. Then, it recalculates the pickup current of relays and optimizes the DOCR coordination. The new settings are updated to the DOCRs via communication network so that the DOCRs become best-tuned to the present network operating condition. A single cycle is then completed. For every change of new operating condition, the cycle is executed again. The frequency will also be in function of wind and solar forecast since DGs are intermittent sources.

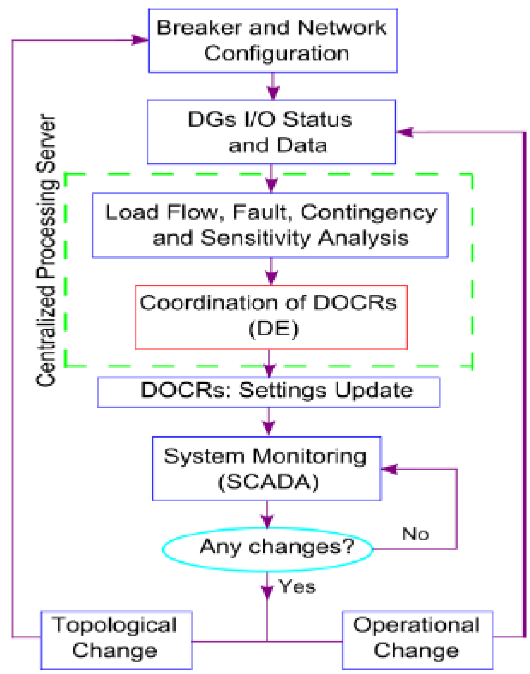

Fig. 7 Adaptive protection scheme

Formulation of Coordination Problem

1) Objective Function:

The purpose of formulating the coordination of DOCRs as an optimization problem is to minimize the primary and backup operation time of relays while maintaining selectivity of relays' operation. It is of great importance to establish appropriate objective function that evaluates the fitness of the settings because this is the key to ensure optimum solution using optimization algorithms.

2) Primary and Backup Relay Constraints:

To coordinate the relays, there must be a time difference between the primary and backup relay. This time difference is called coordination time interval (CTI). In this way, whenever the primary relay fails to extinct a fault, the backup relay enters and tries to extinct the fault after a pre-specified delay. This delay is usually set between 0.2 and 0.5seconds, and 0.3 seconds is used in this paper. The following are the demerits of the paper.

- Harmonics in the level of 3.32%.

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- Hysteresis control has not been implemented
- Memory elements are needed in order to do last tracking error based control.

The main drawbacks of this scheme are its relatively higher cost and larger size resulted from its complicated power stage topology and control circuits. Also, existing systems, the harmonic content is too high, as well the power factor is close to unity but not unity.

PROPOSED SYSTEM

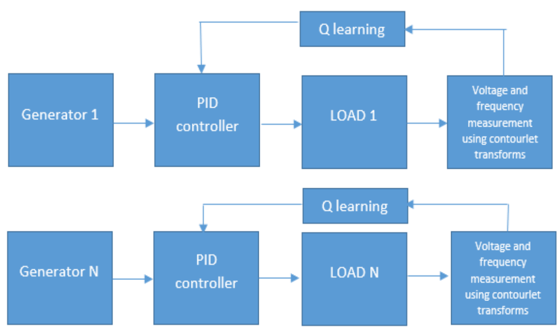

Fig.8 Block diagram of simulation

The implementation in this project is focused towards a hybrid grid, where, the generated power is the combination of both a micro grid and AC main grid. However, the power delivered to the load does not satisfy the load demands due to practical issues of low penetration or faults in the AC main grids.

Contourlet transforms produce Approximation and detail coefficients after the transformation of the data.

Actually approximation coefficients are the low frequency components estimated from the voltage and current. However, detail coefficients contains the information of any discontinuity in the input voltage and current or any abnormal sudden increase in the amplitude. Therefore, based on the magnitude of the details coefficients, the faults are identified.

The value of these coefficients are applied to Q learning approach where the states are observed and actions are produced based on the target state. Awards are given to the actions if the required state is achieved.

Here, the main target is perform the load shedding if abnormal power demand is initialized from the loads. However, the target is to fulfill all the loads and at rare case, shedding may be done when the things of out of hand.

Therefore, at any state, based on the power demand and power generated, the amount of power is controlled using a PID controller. Under an extreme condition the loads are shed to protect the micro grid sources. So, at all instants, the load shed is tried to avoid and or at least keep it minimal.

Based on the intensity of the faults, the trip is generated to isolate the micro grid from macro grid.

SIMULINK MODEL OF UPQC

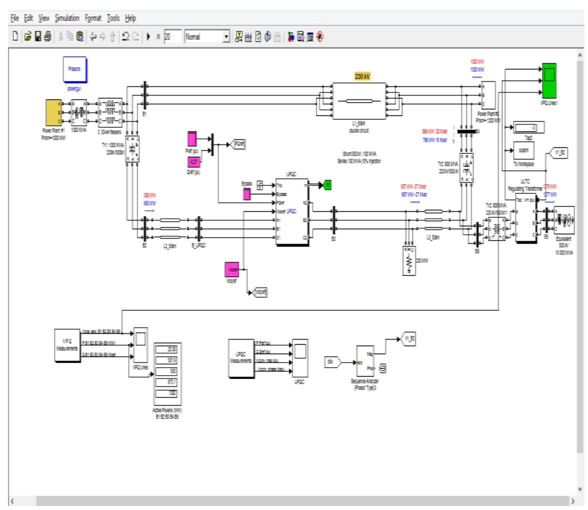

Fig. 9 Simulink model

The model shown is a power system with two generators interconnected via B1, B2,…B5. The solar power is penetrated via a three power AC source after it is inverted. For simplicity, PV panel and inverter has not been done and shown. The power applied to the load is regulated by UPQC. The overall performance is viewed from the scopes available in matlab library.

At normal penetration of solar power (500KV)

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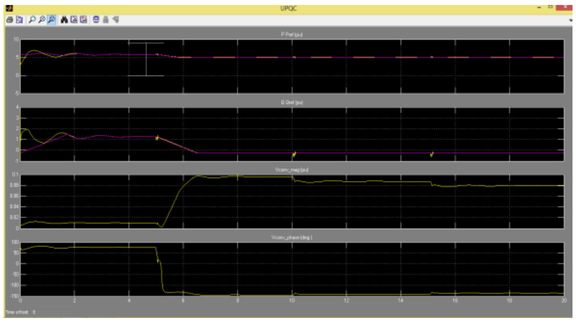

Fig. 10 Real and Reactive Power during Normal Penetration of Solar Power (500KV)

The above diagram shows the ac output when the solar penetration is at 500KV. The real power is set at 5.87 p.u and Q set at =0.27 p.u. Also we can observe that UPQC settles at the above specified real and reacative magnitudes at the set time of 5s. Also, it is shown the voltage magnitude of phase Vab and its angle. Real power and reactive power set to 5.87 to 5 and -0.27 respectively. UPQC functions are stable.

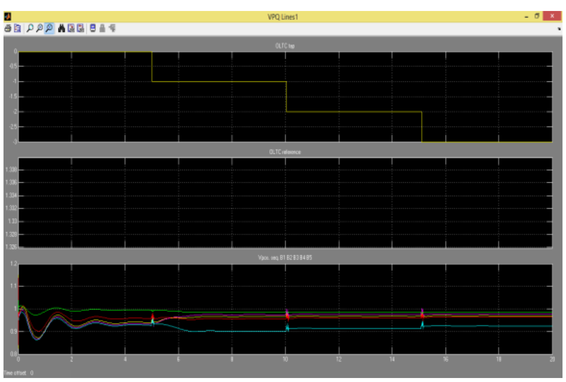

Fig. 11 OLTC Position of the System during Normal Penetration

The above figure shows the tap positions of the OLTC under normal penetration and its value is keep on reducing because the penetration is normal. Also shown in diagram is, voltage magnitudes at buses B1, B2, B3, B4 and B5.

At over penetration of solar energy (1000KV)

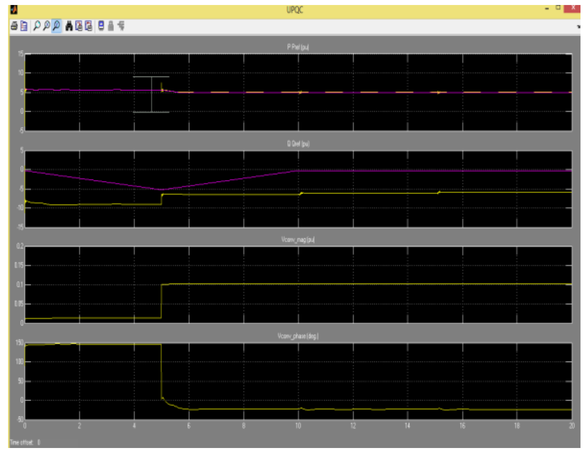

Fig.12 **OLTC Position of the System during Over Penetration**

The above diagram shows the ac output when the solar penetration is at abnormal penetration of 1000KV. The real power is set at 5.87 p.u and Q set at =0.27 p.u. Also we can observe that UPQC settles at the above specified real and reactive magnitudes at the set time of 5s. Also, it is shown the voltage magnitude of phase V_{ab} and its angle. We can note that reactive power never settles down, which may spoil the source due to variation in huge rotor angle.

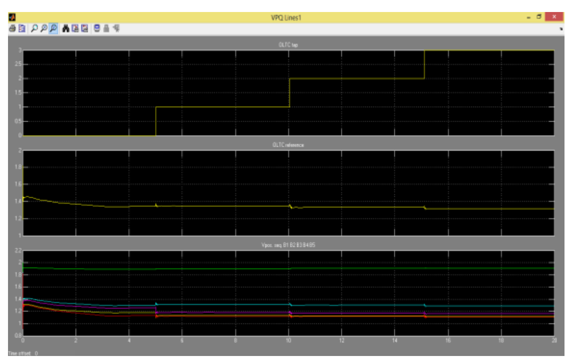

Fig.13 OLTC Position of the System during High Penetration

The above figure shows the tap positions of the OLTC under at an abnormal penetration of 1000KV and its value is keep on increasing because

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the penetration is abnormal. This is controlled by an automatic control of OLTC tap changers and only less power injection is done to the transmission line. Also shown in diagram is, voltage magnitudes at buses B1,B2,B3,B4 and B5. It is seen that UPQC performance is maintained same even at higher penetrations.

After properly setting the tap parameters

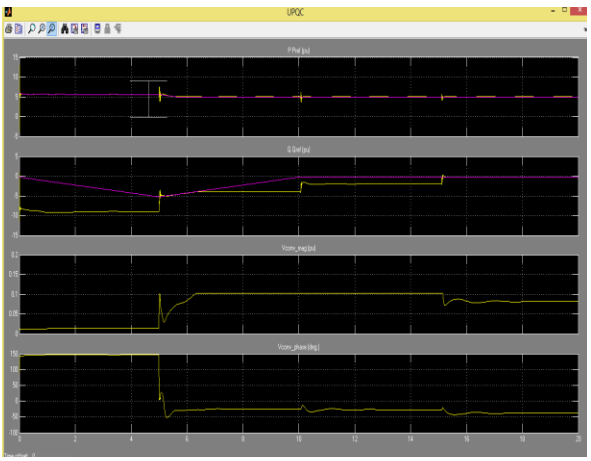

Fig. 14 Real and reactive power after Properly Setting the Tap Parameters

The above waveforms shows the significance of employing OLTC in maintaining the stability of P and Q values as per the set target of 5.87pu and -0.27 pu of P and Q respectively. Though there is a very small instantaneous glitches in the output values, we may neglect it. As over all, the stability is improved. The glitches are because of instantaneous switching of OLTC to new tappings based on the input solar penetration.

Taping step vs stability of Q ref

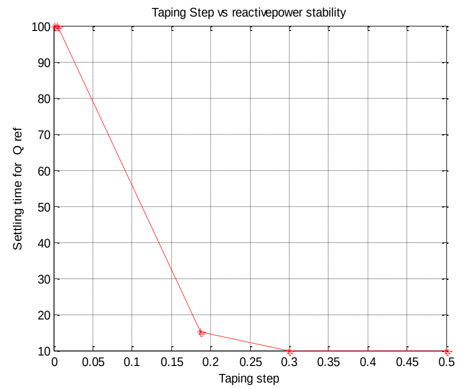

Fig.15 Tap changing time

X axis-Tapping step

Y axis – Settling time

The above figure shows that when the tapping step is more, settling time is less. For zero tapping, the system remains almost unstable and take 100 s or more for settling. When the tapping step is more than 3, the settling time is almost near to zero.

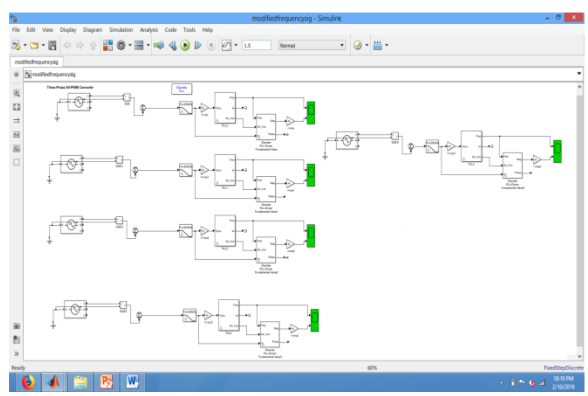

Fig.16. Frequency variation analysis

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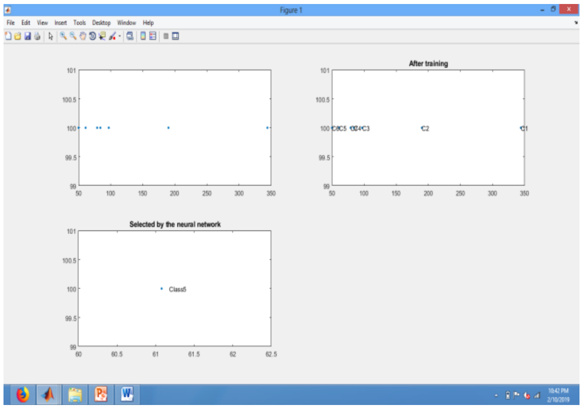

Fig.17 BPN selection

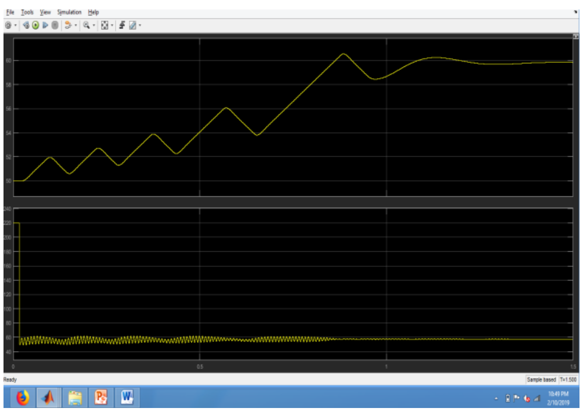

Fig.18 Frequency settling duration

CONCLUSION

In this project, the phenomena of variation in the rating of the UPQC system with the variation in input solar penetration has been modeled and studied based on Q learning algorithm. With variation in input source voltage from solar panels, (it will affect the fundamental load reactive power sharing) has been studied by formulating the generalized VA loading equations of UPQC systems controlled various controller actions. An OLTC has been installed to identify the excess power injection and vary the load tappings based on the input penetration levels. Based on the conceptual study made, an algorithm has been developed to identify the minimum possible VA rating of the UPQC system and that results in the corresponding optimal displacement angle, series inverter, shunt inverter, and series transformer ratings.

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