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Design and Implementation of Smart Energy Management System for Stand-alone Micro-hydro Systems

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Abstract- The Thesis work mainly focuses on uncontrolled hydro turbine feeding a single load. A STATCOM is proposed in a place which is based on Matlab simulation involving synchronously rotating dq reference. As STATCOM is designed for unity power. A battery is connected on the dc side which is charged & discharged by the bidirectional activity of STATCOM. This action helps to keep the frequency constant which is very critical in an isolated grid. The STATCOM also performs other functions like voltage regulation, harmonic elimination & neutral current compensation. & by the use of STATCOM system can Reached To Steady Stat Condition By The Under Simulated Time & Power Quality Will Be Improved.

Keywords- Energy source, statcom, hydropower, Smart Energy Management System, Micro-hydro Systems

I. INTRODUCTION

Today society is to a great extent subject to its vitality supply. Power frames the essential wellspring of vitality. Lighting, warming, cooling, correspondence, transportation, producing, handling enterprises, are all reliant on power. Financial advancement of a nation is reliant on vitality. Financial development worldwide has tripled the power utilization in the previous three decades[2]. The essential vitality hotspots for creating power are coal, common gas, hydro & atomic parting. Every source has constraints, the fossils fills because of its restricted supply, nursery gasses, & is non-renewable sources; hydro force is subject to the precipitation for force era. New power era advances are produced to defeat the detriments of the nonrenewable sources & hydro power. Renewable vitality advances, for example, wind power, sun oriented force, and tidal, geothermal is utilized for vitality era. The employments of renewable-vitality sources are expanding quickly in the late years.

1. Sources Of Electric Energy- In this section we describe the electric energy and its non conventional and conventional source of energy.

2.Conventional Sources Of Energy-Coal, Petroleum (oil), & Natural Gas are the three routine sources of energy utilized as a part of warm power station to produce power. Coal is the principal heat hotspot for power era in many nations. Coal &natural gas are scorched in extensive heaters to warmth water to make steam & to produce hot burning gasses that pass specifically through a turbine, turning the blades of the turbine to create power. Petroleum can likewise be utilized to make steam to turn a turbine. Lingering fuel oil, an item refined from unrefined petroleum, is regularly the petroleum item utilized as a part of electric plants that utilization petroleum to make steam

3. Non-Traditional Sources Of Energy-Atomic Energy is the vitality that is caught inside every molecule. An atom's nucleus can be part separated. This is known as parting. When this is done, a tremendous measure of vitality as both warmth & light is discharged by the start of a chain response. This vitality, when gradually discharged, can be saddled to create power. Starting 2011, India had 4.8 GW of introduced power era limit utilizing atomic powers. India's atomic plants created 32455 million units or 3.75% of aggregate power delivered in India. Hydropower is one of the best, least expensive, & cleanest well spring of vitality, this is in actuality one of the most punctual known renewable vitality

sources, in the country (since the start of the twentieth century).[4] Hydro force is produced from the flowing & falling water, stream flow & from sea waves & tides. The energy in the streaming & falling water can be utilized to create electricity. The present introduced limit of hydro force starting 30 June 2011 is around 37,366.4 MW which is 21.53% of aggregate power era in India.

II. INTRODUCTION OF MICRO HYDRO POWER SYSTEM

India has extensive electricity coverage, including rural areas. Micro hydro is often used in autonomous or semiautonomous applications to replace diesel generators or other small scale power plants or to provide electricity to rural populations. Ninety-five percent of the rural population is served through the grid. Even the more isolated areas are serviced through diesel generators, solar, & mini-hydro sources. The common barrier in the development of micro hydro project is the capital cost which is relatively higher than conventional power plant. Maximizing local content by utilizing locally manufactured components & designing correct components selection & sizing with appropriate operation strategy will alternatively reduce the project costs[7].

1. Brief Description Of Micro Hydro Power System Generally, there are two types of micro hydro system, flow of stream & storage type. However, in this research, the system based flow of stream as Figure 1 is chosen as the capital cost is lesser compared to storage type & easier been conducted. A micro hydro system converts the potential energy of water into electricity by the use of flowing water[9]. This water flows in water streams with different slopes giving rise to different potential for creating heads, varying from river to river. The capacity of power is depends on the head & flow rate as Figure.2.

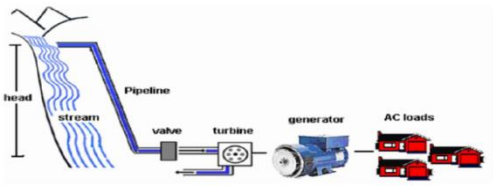

Fig1: Typical micro-hydro systems

Fig.2: Flow rate, Q & Head, H of a stream.

IV. POWER QUALITY

PQ alludes to attributes of power at a given point on the conveyance way, as it identifies with the similarity between the power supplied on a system & the heaps associated with that system. So, everything in the middle of "force is off" & "power is on" identifies with Power Quality. Dependability contrasts from Power Quality. It alludes to lost force at the conveyance point just (see chart underneath).Figure no 3 shows the power quality domain.

Fig 3 Power Quality Domain

In more specialized terms, a force quality aggravation is connected with the deviations in the extent & recurrence of the sinusoidal waveform. A deviation in the sinusoidal waveform may happen when force stays on & a transmission intrusion does not happen (e.g. the lights remain focused, it might glimmer or diminish). It can take numerous structures, for example, voltage hang, stage unbalance & voltage swells, transient unsettling influences, flitting intrusions, & long haul enduring state waveform twists.

1.Power Quality Problems & Issues- A recent survey of Power Quality experts indicates that 50% of all Power Quality problems are related to grounding, ground bonds, & neutral to ground voltages, Ground Loops, Ground Current Or Other Ground Associated Issues. Electrically Operated Or Connected Equipment Is Affected By Power Quality. Determining The Exact Problems Requires Sophisticated Electronic Test Equipment. The Following Symptoms Are Indicators Of Power Quality Problems:

- Piece Of Equipment Mis-Operates At The Same Time Of Day,
- Circuit Breakers Trip Without Being Overloaded.

- Equipment Fails During A Thunderstorm.
- Automated Systems Stop For No Apparent Reason.
- Electronic Systems Fail Or Fail To Operate On A Frequent Basis.
- Electronic Systems Work In One Location but Not in another Location.

The Commonly Used Terms Those Describe The Parameters Of Electrical Power That Describe Or Measure Power Quality Are Voltage Sags, Voltage Variations, Interruptions Swells, Brownouts, Blackouts, Voltage Imbalance, Distortion, Harmonics, Harmonic Resonance, Interharmonics, Notching, Noise, Impulse, Spikes (Voltage), Ground Noise, Common Mode Noise, Critical Load, Crest Factor, Electromagnetic Compatibility, Dropout, Fault, Flicker, Ground, Raw Power, Clean Ground, Ground Loops, Voltage Fluctuations, Transient, Dirty Power, Momentary Interruption, Over Voltage, Under Voltage, Non-Linear Load, THD, Triplens, Voltage Dip, Voltage , Blink, Oscillatory Transient Etc. The Issue Of Electric Power Quality Is Gaining Importance Because Of Several Reasons.

V. METHODOLOGY

The Execution Of Power Area In India Is Investigated With The Assistance Of Chose Non-Money Related & Budgetary Pointers. Non Money Related Markers Are Per Capita Vitality Utilization, Utilization Per Capita, Introduced Limit, Gross Era, Influence Buy, Deals, T&D Losses, Number Of Buyers. Money Related Markers Are Complete Expense & Income, Net Deficiency/Surplus & Working Shortfall/Excess, Normal Cost & Tax, Cost Recuperation Proportion, Working Proportion, Net Benefit Rating , Working Benefit Proportion, Quantifiable Profit & Profit For Capital Utilized. In This Section The Methodology Of Proposed Work Is Descuss.

1.Scheme Of Micro Hydro Plant

A variable rate drive Permanent magnet Synchronous Generator in cross breed with a hydro driven squirrel confine Induction Generator alongside a battery is likewise talked about [7]. Investigation of voltage control for a self-energized acceptance generator utilizing a current-controlled voltage source inverter (CC-VSI) which additionally performs elements of burden adjusting & symphonious end is likewise examined [8]. Load remuneration utilizing STATCOM as a part of three-stage, three-wire conveyance framework under different source voltage & delta associated load conditions is likewise talked about [9]. The schematic graph of the STATCOM with a general framework is appeared in Fig.4. A Synchronous Generator is sustained by an uncontrolled hydro turbine. These turbines dependably deliver an appraised power which is supplied to the generator. The exciter voltage is constrained to 2pu which is only adequate for it to deliver evaluated voltage amid full load condition.

On the dc side of the STATCOM a dc battery is associated. In this manner, it can likewise give genuine force at whatever point required. The measure of genuine force it can give relies on upon the limit of the battery. It can likewise assimilate overabundance power if there should be an occurrence of softly stacked condition & in this manner the STATCOM demonstrations both as a voltage & recurrence controller. The control structure for a STATCOM depends on Vector Control standard where synchronously pivoting reference edge is considered [12].

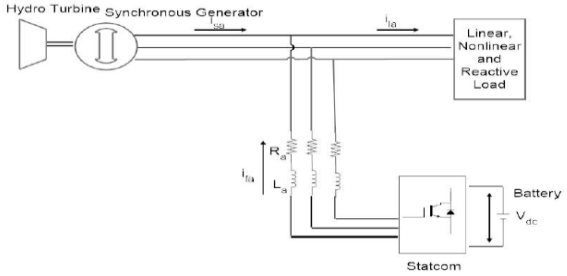

Fig 4. Schematic graph of Micro hydro System.

2. Reference Current Generation For Proposed Statcom

The control structure for STATCOM depends on synchronously pivoting reference outline hypothesis as appeared. When the three stage voltages are changed in dq amounts with point synchronized; crest voltage is seen on the d hub as it were. A three stage PLL is utilized to synchronize & therefore compute the position of change point Θs. Fig.5. shows vector control for STATCOM.

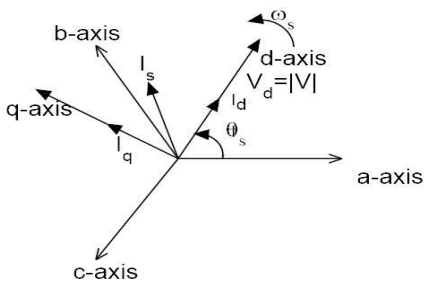

Fig.5. Vector control for STATCOM

The current in dqo casing is given by

$$\begin{pmatrix} I_q \\ I_d \\ I_o \end{pmatrix} = \frac{2}{3}\begin{pmatrix} \cos\theta & \cos(\theta-\frac{2\pi}{3}) & \cos(\theta+\frac{2\pi}{3}) \\ \sin\theta & \sin(\theta-\frac{2\pi}{3}) & \sin(\theta+\frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{pmatrix}\begin{pmatrix} I_a \\ I_b \\ I_c \end{pmatrix}$$

Genuine & Reactive force in dq edge is given by

$$P=\frac{3}{2}(V_dI_d+V_qI_q) \quad \& \quad Q=\frac{3}{2}(V_qI_d-V_dI_q)$$

Here, the generator pace is contrasted & the reference & went through a PI controller to create Ifreq.

$$I_{freq}=I_{freq}(n-1)+K_{pf}(\omega_{err}(n)-\omega_{err}(n-1))+K_{if}(\omega_{err}(n)$$

3.Data Collection

The information for the study were gathered from both the essential & auxiliary sources. In any case, auxiliary source has been a noteworthy source from which real parcel of the required information are gathered. a. Essential information were gathered by perceptions & from the reactions of casual talks & organized meetings with the authorities of the Department. The distributed information was additionally gotten from different books, diaries, productions & periodicals on force & vitality. The optional source materials are recorded in the reference index. For this research we used the base paper parameter for the micro hydro power plant for the making difference using FACTS device for the power quality improvement & voltage compensation.

4.Conventional Statcom- This section describe about conventional STATCOM

5.Compensation Principle Of Statcom-STATCOM is a converter type FACTS device, which generally provides superior performance characteristics when compared with conventional compensation methods employing TSCs & TCRs. STATCOM based on VSC topology utilize either GTO or IGBT devices. A functional model of a STATCOM is shown in Figure 6. In Its Simplest Form, The STATCOM Is Made Up Of A Coupling Transformer, A VSC, & A DC Energy Storage Device. The Energy Storage Device Is A Relatively Small DC Capacitor, & Hence The STATCOM Is Capable Of Only Reactive Power Exchange With The Transmission System.

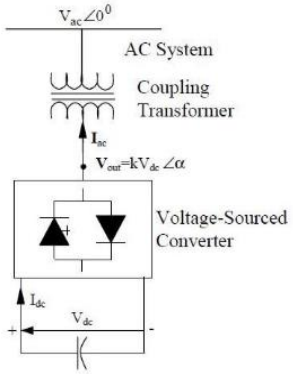

Fig 6 Functional Model of A STATCOM.

If A DC Storage Battery Or Other DC Voltage Source Were Used To Replace The DC Capacitor, The Controller Can Exchange Real & Reactive Power With The Transmission System, Extending Its Region Of Operation From Two To Four Quadrants. In Order To Understand The Compensation Principle Of STATCOM, Two Sources V1with A Phase Angle Of & V2with A Phase Angle Of 0° Connected Together By Means Of An Inductive Link Of Impedance (R +J X) Ohms As Shown In Figure 7 Are Considered. In The STATCOM Principle, The Source V1is The Power System Voltage At The Bus Where The STATCOM Is Connected, V2is The AC Voltage Generated By The STATCOM Inverter, X Is The Reactance In The Line, R Is The Total Loss Resistance In The Link Comprising Of The Winding Losses In The Link Inductor, Interface Magnetic, The Inverter Switches & Snubber Etc. Assuming Is Small & R << X, If V2represents The STATCOM Condition & If The Active Power Flowing Into The Source V2is Constrained To Be Zero, The Power Delivered By The Source V1& The Reactive Power Delivered To The Link By The Source V2will Be Given By The Following Equations .

The aim of the PWM control scheme is to maintain constant voltage magnitude at the PCC, under system disturbances. The control system only measures the RMS voltages at the PCC, i.e., no reactive power measurements are required. With these converters, the AC output voltage can be controlled by varying the width of the voltage pulses. With PWM technique, the output of each converter pole is switched several times during a fundamental cycle between the positive & negative terminals of the DC source. PWM requires a considerable increase in the number of switch operations, thereby it generally increases the switching losses of the converter. However, the always increasing switching

frequency of modern solid-state power switches used in FACTS controllers made possible the use of PWM in high power applications. The implementation & the design for the PWM controller are simpler than for phase control, due to the easy separation of the active & reactive components of the STATCOM output current without a need for a d-q decomposition. In the block diagram, the Phase Locked Loop (PLL) provides the basic synchronizing signal which is the phase angle of the bus voltage,. It is obtained from the zero crossing of the bus voltage. In the case of a sudden change in the power. system, such as cyclic loads, it takes about half a cycle of voltage for the PLL to be synchronized with the new voltage phase angle, plus the signal processing delay.

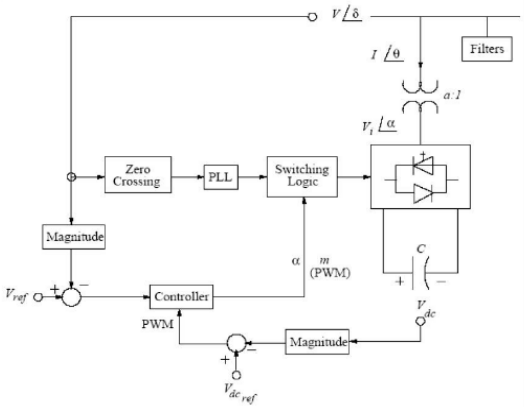

Fig 7 Block diagram of a STATCOM with PWM voltage control.

During this time the STATCOM operates at the previous phase angle, while the bus voltage phase has changed.Depending on the amount of phase angle change & whether it is increased or decreased an uncontrolled real power &therefore reactive power exchange would occur between the STATCOM & the transmission line during this inherent PLL delay. PWM controls are becoming a more practical option for transmission system applications of VSC-based controllers.

VI. MATHEMATICAL NONLINEAR MICROHYDRO POWER GENERATION MODEL

Numerical displaying is accomplished for separated smaller scale hydro power framework utilizing Pelton hydro turbine. For high heads & low water stream rate Pelton turbines are utilized. Hydro-electric framework segments are characterized for the most part into two gatherings. One is water powered framework segments including the turbine, penstocks, passage & surge tank. Other is the electric framework parts including the synchronous generator**.**

1.Hydraulic Framework Demonstrating

The Hydro power yield, as the turbine model depends on conditions for enduring state operation, is given by,

Pt = ρgQtHe (1)

Where,

Pt = turbine power,

ρ = water thickness,

Qt = water stream,

He = viable head. If there should be an occurrence of Pelton turbine, it gets to be:

Pt = ρQtVt (V1 – V2) (1 + mcosβ) (2)

Where, Vt = drive pace of the turbine, V1 = water speed in the contact of the plane with the basins, m = report of V1 & V2, β = edge amongst V1 & V2.

2. ELECTRICAL FRAMEWORK DISPLAYING

The generator is synchronous machine, model is considered as a traditional fourth-degree model as given underneath:

Ed = Iq (xd' - xq)/(1 + sT'qo) (3)

Eq = Id (xd' – xd)/(1 + sTdo) + Efd/(1 + sTdo') (4)

Where, Ed = direct pivot transient voltage,

Iq = quadrature hub armature current,

xd' = direct hub transient reactance,

xq = quadrature hub reactance of generator,

T'qo = quadrature pivot open circuit time consistent,

Eq = quadrature pivot transient voltage,

Id = direct hub armature current,

xd = direct hub synchronous reactance,

Tdo' = direct hub open circuit time consistent,

Efd = direct hub field voltage.

2. Exciter Modeling

Efd = (Vtr – Vt – Vs) KE/(1 + sTE) (5)

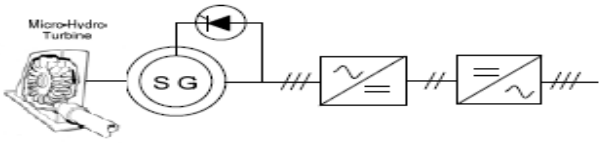

Fig.8. Variable velocity synchronous generator

with AC-DC-AC converter piece graph Vs = Efd sKF/(1 + sTFE) 68)

Where, Vtr = reference estimation of the termina voltage,

Vt = generator terminal voltage,
Vs = settling transformer voltage,
KE = exciter pick up, TE = time steady of exciter,
KF = current increase of stabilizer,
TFE = time consistent of stabilizer circuit.

VII. SIMULATION RESULTS

The parallel operation of disengaged offbeat generators execution is exhibited with adjusted/lopsided, direct & non straight loads. The capacity of battery is accomplished for burden leveling & a consistent force is kept up at generator terminals.

The proposed system is modeled & simulated using MATLAB environment. The configuration includes the micro-hydro turbine, synchronous generator, a back-to-back AC-DC-AC converter, SG (8.1kVA), power quality analyzer, RL-load with 3 Mvar capacities STATCOM connected through it. The linear load applied for simulation time 2 sec, then the load observed high power requirement so the battery supplies additional power required by consumer loads. The function of battery is achieved for load leveling & a constant power is maintained at generator terminals. Maturing full load is expelled at 2sec; the battery begins charging by the all created power. So thusly the battery charging & releasing furthermore his controller keeps the produced power steady & enhanced force quality by keeping up terminal voltage & frequency.(fig 9.1to 15)

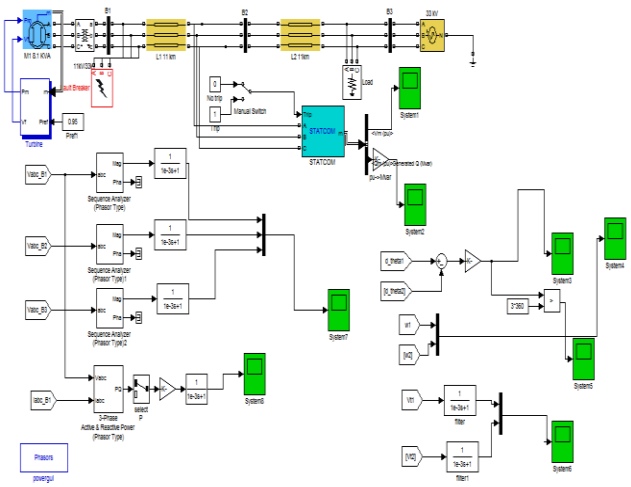

Fig 9. Simulink Model for Micro Hydro Power plant

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In the fig 9 we can see that at the simulation time .256 sec fault is occurred in the system in the existing thing. STATCOM when incorporated in the system it try to maintain the fault at .256 sec at the .072 pu for the three phase line voltage .

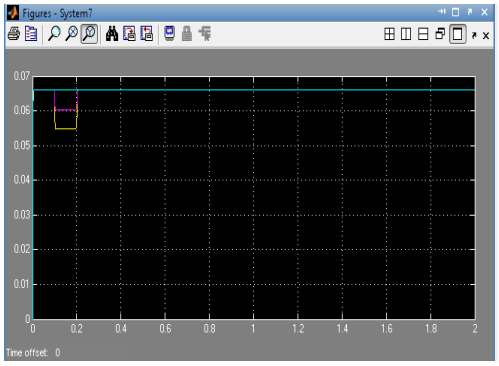

Fig 10 Bus Voltage V_{abc} of hydro plant utilizing STATCOM& Without STATCOM Respectively

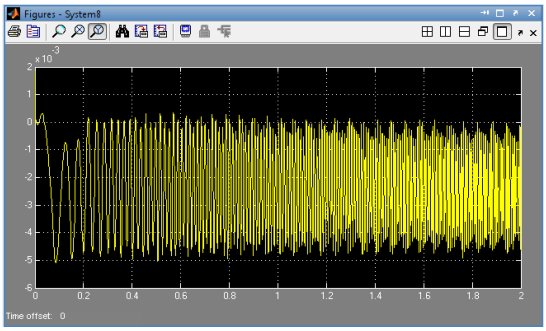

Fig 11 Bus Current Iabc of micro hydro system

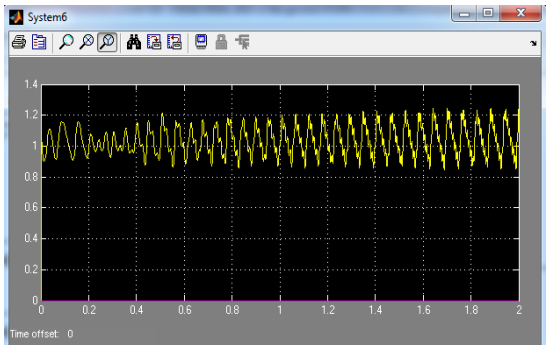

Fig12 Reference Filter Voltage Excitation

The bus current will be same as suppose we incorporated STATCOM in the system, it will not effect to bus line current in the system.

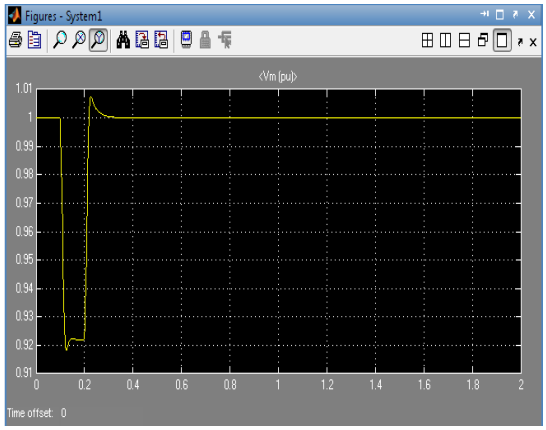

Fig 13 a Voltage Output of STATCOM at connected & disconnected situation.

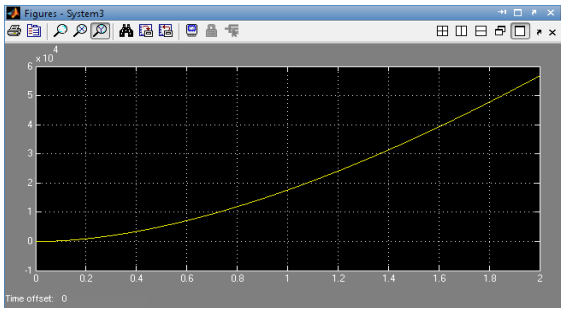

Fig 13 b Voltage Output of STATCOM at connected & disconnected situation

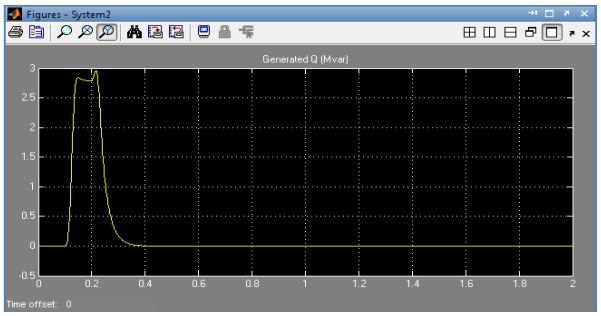

Fig 14 Rotor Angle Deviation of Hydro Motor

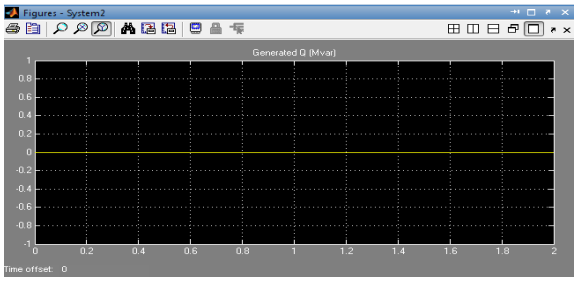

Fig 15 Reactive Power change Using STATCOM& Without STATCOM Respectively

We can see that in the given figure 15 that when STATCOM is not incorporated in the system its showing the no reflection in the graph, but when STATCOM connected in the Micro hydro power plant,we can see that at the simulation time.256 at the faulty condition STATCOM maintain the absorb/ generate the power for maintaining the power quality & try to reached system steady state condition, in the graph we can see that it is going to the steady state at .5pu of reactive power in negative quadrant because it generating the power for the system reached steady state.

Finally when we connect the FACTS device STATCOM to the system it maintain the power quality with voltage compensation for the micro hydro system at the rated rating 8.1 KVA with 50 Hz frequency generator system. By the help of this system also we can try to incorporate STATCOM for the better improvement of power quality in real time example.

We will now apply a 3-phase fault & observe the impact of the STATCOM for stabilizing the network during a severe contingency. Reprogram the 'Fault Breaker' block in order to apply a 3-phase-to-ground fault. Verify that the STATCOM is in fixed susceptance mode with B_{ref} = 0. Start the simulation. By looking at the d_theta1_2 signal, you should observe that the two machines quickly fall out of synchronism after fault clearing. Then STATCOM block menu & change the STATCOM mode of operation to 'Voltage regulation'. It will now try to support the voltage by injecting reactive power on the line when the voltage is lower than the reference voltage (1.008 pu).

VIII. CONCLUSION

We have already discussed about the micro hydro system with using the FACTS device and without the FACTS device. We are having the number of facts device available for the power quality improvement. A STATCOM is proposed in a position of a customary which depends on vector control plan including synchronously pivoting dq reference. STATCOM is intended for solidarity power. A battery is associated on the dc side which is charged & released by the bidirectional movement of STATCOM. The STATCOM likewise performs different capacities like voltage direction, & reactive power control & provide better result for the voltage compensation & reactive power control. This work revealing the micro hydro

system to reached at steady state by use of facts device STATCOM at the simulated scale .256 sec for the under simulated time 2 sec. showing the reactive power at the faulty condition .

IX. FUTURE SCOPE

There are number of Plant is running for the electricity generation and using the FACTS device, in future also we can use the hybrid method for comparison purpose only for Micro hydro power plant. We can use different technique foe placement o facts devices in network to improve the results.

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