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Efficient and Novel Technique for Electronic Load Controller to Compensate the Current and Voltage harmonics for Micro-hydro Power Plant

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ABSTRACT: Electronic load controller (ELC) has been anin-dispensary part of governor free Micro hydro plant forfrequency control for a long period of time. ConventionallyELC consists of thyristor controlled dump load system; inwhich firing angle regulates the amount power to be fed intodump load. Such ELC units suffer many drawbacks, includinginjection to current harmonics, drawing high reactive current from the source, and so on.Electronic loadcontroller (ELC) is a cost-effective solution for this application. Resistive (dump) load at an equal rating ofgenerator is used to maintain constant voltage and frequency at the load perturbations. However, the systemreceives electrical and mechanical stresses as it operates at full load throughout the life which causesdegradation of its component and lifetime reduction. This study tries to address these issuesby introducing a novel ELC. The proposed ELC systemaccommodate traditional active power filter (APF), STATCOMand dc chopper for compensating unbalance, harmonics andreactive power, irrespective of all loading conditions. Itoperates on instantaneous p-q based current injection method;by which harmonic, unbalance and reactive current fed to the ELC. The proposed system is simulated in MATLAB/Simulink and validated results obtained from MATLAB/Simulink model.

KEYWORDS- Micro hydro power plant, Electronic load controller, harmonics, non-linear load

I. INTRODUCTION-

Consumers who are located at city centres and a few remote places receive electric power conveniently from conventional power plants like thermal or hydroelectric generating stations. But this is not the case with consumers located in hilly and a few remote areas, where economic and logistic constraints come into effect and it is not possible to install a receiving substation to receive and distribute electric power, leave alone the maintenance of electrical equipment's in these remote areas. In such situations Micro Hydro Systems (MHS) can be installed to deliver power, provided water resources with potential energy are available. Like any conventional generating stations even Micro Hydro Systems require controlling, monitoring and distributing circuits for power flow from the generating stations to the load.Conventional hydro electric generators use speed governor and also excitation controller to regulate the speed, frequency and voltage generated and fed to the user loads. Since the cost of speed governor is high with associated problems in hydraulic systems. Micro Hydro Systems do not use speed governors. However, the speed is governed indirectly by maintaining constant load on the generator and hence the turbine by using electronic circuits. Thus by using ELECTRONIC LOAD CONTROLLER (ELC) the load on the generator is maintained constant for a given water input. An ELC is a solid-state electronic deviced esigned to regulate output power of the generator used in the microhydropower system. Maintaining a near-constant load on the turbine, the generator generates a stable voltage and frequency for a given constant water input. ELCs react so fast to load changes that speed changes are not even noticeable unless a very large load is applied. The turbine rotational speed depends on the mechanical powerof the water flow, and the generator speed depends upon the loadconnected to the generator [9]. If the water flow into



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turbinechanges or the consumer load connected to generator changes, thiscauses an equivalent decrease or increase in the generator outputvoltage and frequency [10]. ELC, also known as a solid-state electronicdevice, is intended to control output power of the generatorused in the MHPP [6]. In case of constant water flow into turbines,ELC keeps almost constant load on the generator by switching onand off dummy loads if consumer loads connected to generatordecrease or increase. Hence, on a given constant water input, thegenerator generates a stable voltage and frequency. The reactiontime of ELC is very fast, because it switches on and off dummyloads through electronic switches [1]. ELC keeps frequency andvoltage at agreed value devoid of the need of operator intrusions. Switching of dummy loads at peaks of sine waves canproduces high sparks that damage electronic switches and consumerloads connected to the generator [2]. Also, the output of the generator will no more remains a pure sine wave [3]. Thispaper presents an effective technique through which switchingof dummy loads at zero crossing will reduces sparks in switchingand minimize damage of electric appliances [4]. The results showa pure sine wave in dummy loads and consumer loads connected to the generator in case the zero crossing switching technique isused. Fig. 1, shows a schematic diagram of a powerhouse with anELC that keeps generator at full load. In this Fig. 1, Q shows thewater discharge, H shows head. The turbine produces mechanical energy and the generator converts this mechanical energy intoelectrical power shown by P_G .



Fig. 1.Power house with an ELC.

II.PROPOSED METHODOLOGY

The layout consists of three subsystems; turbinegeneratingunit, ELC unit and load unit (Figure 2). Thegenerating unit includes a synchronous generator withexcitation control for voltage regulation. The prime moverinclude cross-flow pelton turbine with governor-freeoperation, so the turbine is exposed to free flow of water. Thus the generator is running at its rated value throughout the time. The load unit has bridge rectifier (thenon-linear load), 3-ph balance and unbalanced load. The ELCunit consists of a voltage source converter (VSC) withembedded current chopper at the DC side. It acts as theactuator for the speed control by passing the surplus power tothe resistive dump load. The ELC can functions to fulfil broader objectives: (i) acts an APF to supply harmoniccurrent, (ii) recirculates the feeder current to balance thegenerator line current, and (iii) regulates the systemfrequency similar to the traditional ELCs. When desired, theELC can also supply the reactive power as in STATCOM. Thereby the generator would supply balanced, harmonic free and active component of load current, keeping voltage andfrequency within acceptable margin. The study adopts the standard dynamic model of a salientpole SG, with d-q based modelling suitable for transientstudy. For this, the 7th order dynamic model of synchronousmachine is adopted, which features dynamics of statorwindings, field winding,



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damper windings, and electromechanical), represented in the rotor reference frame [5]. The prime-mover model, consists of governor-free hydraulic turbine, similar to the constant dc load motor drive represented by

$$T_m = C_1 - C_2 \omega_r$$

where, C_1 is function of water flow rate and the C_2 is thefeedback coefficient of generator speed. The load elements consist of non-linear and unbalancedload. The non-linear part is represented by rectifier fed dcload, while the constant impedance load (with differentmagnitudes) represents the unbalance part. The rectifier ismodelled as diode based uncontrolled rectifier, while chopperis modelled as IGBT based switch. The ELC model incorporates an IGBT based VSC withthree-phase four-wire topology [6]. It operates on currentcontrolled mode with centre-tapped neutral wire to provide the path for the neutral current. Besides, the ELC alsoincludes a DC chopper to deviate controlled current through dump load connected at the DC bus. To understand theworking principle the ELC system, consider a synchronousgenerator supplying the nonlinear and unbalanced current. The unbalance and harmonicscontent of the current has the adverse impact on thegenerators. To pass the only fundamental and balancedcurrent a shunt path should be introducedthrough which the undesired current componentscould be passed. Therefore, the proposedscheme combines the feature of active power filter (APF),STATCOM and conventional ELC in a single unit, in whichthe reference current to be injected by the ELC is calculated by instantaneous p-q theory [7]. Hence it is named as anadvanced ELC for the micro hydro system. The detailedcontrol scheme of the ELC is discussed in following section.



Figure 2. Layout of proposed MHP-ELC system

III. PROPOSED CONTROL SCHEME

The main control scheme is based on the generation of reference current for ELC and tracking it accordingly. Forgeneration of reference current, the instantaneous powertheory, or p-q theory is utilized, which is valid for valid forsteady-state or transitory operations for 3-ph, 4-wire system. The p-q theory consists of an algebraic



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transformation(Clarke transformation) of the three-phase voltages and currents in he a-b-c coordinates to the α - β -0 coordinates, followed by the calculation of instantaneous power components.



Figure 3.Power components of p-q theory in a-b-c coordinates

The p-q theory is one of several methods that can be used in the control active filters. It presents some interesting features, namely: (i) inherently a three-phase system theory, meaning that it can be applied to any three-phase system (balanced or unbalanced, with or without harmonics in bothvoltages and currents); (ii) based in instantaneous values, allowing excellent dynamic response; (iii) calculations are simple algebraic expressions; (iv) two control strategies, constant instantaneous supply power and sinusoidal supply current. The calculations presented so far are in Figure 3a and correspond to a VSC control strategy, generating reference current as the controlled variable. The reference current is then compared to the actual values and hysteresis bandcontrol is applied. Likewise, dc-link voltage is regulated by providing similar duty cycle control to the current chopper.

IV.NOVEL ADAPTIVE HYSTERESIS CURRENT CONTROLLER

The hysteresis band current control can be implemented to generate the switching pattern in order to get precise and quick response. The hysteresis band current control technique has proven to be most suitable for all the applications of current controlled voltage source inverters in active power filters. The hysteresis band current control is characterized by unconditioned stability, very fast response, and good accuracy. On the other hand, the basic hysteresis technique exhibits also several undesirable features; such as uneven switching frequency that causes acoustic noise and difficulty in designing input filters. The conventional hysteresis band current control scheme used for the control of active power filter line current is shown in Fig. 3, composed of a hysteresis around the reference line current. The reference line current of the active power filter is referred to as 1,' and actual line current of the active power filter is referred to as I, The hysteresis band current control ended to as formulated as follows:

If i_{ca}< (i_{ca}- HB) upper switch is OFF and lower switch is ON for leg "a" (SA=l).

If i_{ca}> (i_{ca} + HB) upper switch is ON and lower switch is OFF for leg "a" (SA=O).

The switching functions SB and SC for phases B and C are determined similarly, using corresponding reference and measured currents and hysteresis bandwidth (HB). The switching frequency of the hysteresis band current control method described above depends on how fast the current changes from the upper limit of the hysteresis band to the lower limit of the hysteresis band, or vice versa. The rate of change of the actual active power filter line currents vary the switching frequency, therefore the switching frequency does not remain constant throughout the switching operation, but varies along with the current waveform. Furthermore, the line inductance value of the active power filter line currents. The switching frequency of the active power filter system also depends on the capacitor voltage and the line inductances of the active power filter configuration.



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Figure 4.Hysteresis band

V.SIMULATION AND RESULTS

The layout and the component model presented in abovesections are developed in Matlab/Simulink® platform. Byintroducing loading as disturbance input, the control schemeis tested through the responses of different controlledvariables, such as ELC current, source current, dc voltage,system frequency and the THD of source current. Also thesystem under faulted condition is test to evaluate the ridethroughcapability of the system. The following sectionselaborate the findings of the simulation results.



Fig 4. Simulink model of Proposed system

The ELC is functioning as APF consuming theharmonics, while generator supplies only the fundamentalpart. This significantly reduces the THD keeping it below4%. It can also be seen that the dc voltage is kept at itsdesired value through the chopper action. In the similarfashion, the ELC can be operated as STATCOM, in whichthe load reactive power is fed by the ELC and generatoroperates in unity power factor condition. To analyze the THD of the source current, Fast FourierTransform (FFT) is used to measure the order of harmonicswith the fundamental frequency. The total harmonic of the source current is plotted without activeharmonic current compensation which is shown in Figure.

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Fig 5. Load Current, Inverter Capacitor Current, Source Current and source voltage



Fig 6.Active and Reactive power at source side



Fig 6. Active and Reactive power at Load side

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Fig 6. Active and Reactive power suppliedby ELC

VI. CONCLUSION

This study presented an advance ELC system that hasversatile functionalities. The ELC unit consists of a VSC withembedded DC chopper, with multiple functionalities. It is capable to work as conventional electronic governing unit, harmonics, and reactive power and unbalance current compensating unit. By this approach, the generator hasreduced harmonics and unbalanced current injection, and itsinstalled capacity is also minimized. Consequently, thecapital and operational cost associated with MHP system islowered. To realize this, the combined instantaneous p-qcontrol theory (with VSC) and DC voltage regulation (forchopper) schemes were employed. To test the scheme, computation model was developed and simulated inMATLAB/Simulink environment. The result shows that theELC system fulfills the desired objectives, thereby validating applicability of the scheme in the real-time.

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