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REVIEW AND ANALYSIS ON ELECTRONIC LOAD CONTROLLER

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ABSTRACT
This paper presents an extensive review of the performance analysis, design, testing, recent developments and future prospects of an Electronic Load Controller which is generally applied to control the frequency. The paper describes the recent design and developments in the field of Electronic Load Controllers (ELC). This paper describes step by step recent development in the area of Electronic Load Controllers used in hydropower plants. The paper also provides helpful information and resources for the future studies for those interested in the problem or intending to do additional research in the area of ELC and frequency control.

Keywords- Electronic load controller, separately excited induction generators, dump loads, insulated gate bipolar transistors, voltage and frequency controller, utilization of power etc.

I. INTRODUCTION
Decentralised power generation has been welcomed especially in rural areas in the recent time as stand-alone systems using locally available energy sources have become a preferred option. Small systems with less investment to energize local communities are preferred and are found attractive. With increased emphasis on eco friendly technologies the use of renewable sources such as small hydro, wind and biomass is being explored. As these systems are remotely located so it is expected that the systems must be robust, reliable and locally maintained with no or minimal professional intervention which is applied to every part of the system. Also in grid connected systems are very complex and require a lot of investment. So these standalone systems are becoming more popular day by day. Generally local rivers tributaries or small waterfalls energy is harnessed to drive micro turbines which are used as prime movers. Generally induction generators were preferred due to their low cost , availability, ruggedness, etc in the past. Now separately excited synchronous generators are also used as power factor can be effectively controlled in these generators and also it has an in built AVR system.

Generally, low power ratings (less than 100kW) are preferred. These systems are generally composed of runoff river type in which there is no any provision of water storage. In these systems the operating point of the generators has to be held constant at varying consumer loads. Thus a controllable dump load is required which must be connected in parallel to the system so that the total power consumption is held constant at varying loads. Earlier costly governors were used to control the power of these system but from the last twenty years solid state ELC's are being used which are simple , low cost, and accurate with less reaction time. They have replaced the costly system incorporated to fix the operating point of the generator.

The key point of using an ELC is to sense speed and frequency and connect or disconnect the dump load so as to maintain the total load on the generator and turbine constant. An ELC constantly senses and maintains the generated frequency, has high reliability, low maintenance and simple to operate, less expensive, less wear and tear of machinery, low hammering effect. In some of the literature it was found that the dump power is effectively utilized for water heating purpose in the plant.

II. REVIEW OF LITRATURE
This paper illustrates general backgrounds of research and development in the field of deigns, modelling, testing and performance analysis based on over 20 latest published articles. The open literature presents the summary and made necessary assumptions for different aspects of ELC. The necessary weakness and strengths are highlighted. The most recent papers are included in this literature with possible areas of work that can be looked upon in the near future.

This paper was presented in National Conference at Government Women's Polytechnic, Ranchi

In 2001, Jun and Bo [1] proposed a new electronic load controller. In this paper a microcontroller was used as a brain and an IGBT is used as a switch. The method and circuit's performance

In October 2001, Wekhande and Agarwal [2] proposed a new ELC for self excited induction generator with constant voltage and variable speed. This method does not require any real time speed data for its control and it is less costly by minimizing the electronic hardware. Also excitation current also needs not to be found for its operation.

In November 2003, Singh, Gupta and Murthy [3] described the mathematical modeling of self-excited induction generators (SEIGs) with are improved electronic load controller (IELC) for micro hydel applications supplying variety of loads. In small application governor, unit can be replaced by IELC which is simple and cost effective. In this system the current controlled system is used with IGBT as switched in three phases. Also a high frequency DC chopper which keeps the generated voltage and frequency constant in spite of change of balanced/ unbalanced loads. A dynamic model was also developed with stationary d and q axis for determining the behavior of the system is made in this method. The simulated results show that generated frequency and voltage remain constant with change in load. This method also proposes a method to compensate the reactive power into the system.

In January 2004, Singh, Murthy and Gupta [4] described the modeling of an electronic load controller (ELC) for a self excited induction generator (SEIG, is presented. The implemented ELC consists of a rectifier-chopper system feeding a resistive dump load whose power consumption is varied through the duty cycle of the chopper. The dynamic model was also represented for determining the stability of the system. Both the modeling and control technique of the ELC-SEIG are validated through simulated and experimental results

In October 2005, Singh, Murthy and Gupta [5] presented transient analysis of a self-excited induction generator (SEIG) with electronic load controller (ELC) used in stand-alone micro-hydro power generation employing uncontrolled turbines. In view of the need to feed both dynamic three phase induction motor (IM) and static loads from such systems, the transient behavior due to switching in of such loads is of interest and is carried out here. A composite mathematical model of the total system has been developed by combining the modeling of prime mover, SEIG, ELC, and load. Simulated results were compared with the experimental ones, obtained on a developed prototype of an SEIG-ELC system for the starting of an IM and switching in a resistive load.

In March 2006, Singh, Murthy and Gupta [6] presented an analysis and design of an electronic load controller (ELC) for three-phase self-excited induction generator suitable for stand-alone pico-hydro power generation with constant input power. In the paper, the SEIG can be used to generate constant voltage and frequency if the electrical load is maintained constant at its terminals. Moreover, under such operation, SEIG requires constant capacitance for excitation resulting in a fixed-point operation. For this purpose, a suitable control scheme has to be developed such that the load on the SEIG remains constant despite change in the consumer load. The proposed controller was cheap and suitable for hilly areas.

In September 2006, Jaraman and Bryce [7] described the extensive field experience in micro-hydroelectric systems in remote rural communities demonstrates that the use of a typical automatic voltage regulator (AVR), as supplied with a brushless self-exciting synchronous alternator, could be the cause of unsatisfactory system performance. Results were presented from experiments undertaken on a full-scale micro hydroelectric test rig as well as system modeling with PSCAD.

In December 2006, Murthy, Ramrathnam, Gayathri, and Naidu [8] presented the dynamic and steady state performance of a standalone self excited induction generator (SEIG) with digitally controlled electronic load controller feeding single phase and three phase loads. The values of the capacitances were chosen to ensure self-excitation of the machine and to minimize the unbalance between the stator voltages..

In December 2006 Singh, Murthy, Madhusudan, Goel, and Tandon [9] described steady state analysis of self-excited induction generator (SEIG) operating with an electronic load controller (ELC) for regulating its voltage and frequency under varying load condition. The ELC consists of a rectifier and a chopper circuit whose operation

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generates harmonics on AC side of the SEIG system. To achieve adequate performance characteristics of the SEIG with ELC information of harmonic contents and real power is necessary.

In October 2007, Singh, and Kasal [10] proposed a voltage and frequency controller for an isolated power generation system based on asynchronous generator (AG) driven by pico hydro turbine and supplying 3-phase dynamic (asynchronous motor) loads. The proposed generating system along with its controller is modeled in MATLAB using SIMULINK and PSB (Power System Block Sets) toolboxes.

In November 2007, Singh, and Kasal [11] proposed a model for constant voltage and frequency to for Pico hydro power station operating in hilly and remote areas.. For controlling the voltage, a static compensator (STATCOM) is used as a reactive power compensator along with harmonic eliminator and a load balancer while for controlling the frequency; an electronic load controller (ELC) is used to regulate the total active power at the generators terminals. STATCOM is realized using voltage source converter.

In February 2008, Sisworahardjo, El-Sharkh, and Alam[12] proposed small micro turbines for distributed generation of power. Artificial neural network (ANN) was used for the controller for this purpose. In addition, they presented a comparison between the performance of the MT when using traditional PI and ANN controllers.

In April 2008, Kasal, and Singh [13] proposed a decoupled voltage and frequency controller (DVFC) for an isolated asynchronous generator (IAG), also known as the self-excited induction generator (SEIG), used in constant power applications such as Pico hydro uncontrolled turbine driven for feeding three-phase four-wire loads. The proposed controller is used to control the voltage and frequency at the generator terminal independently. The proposed decoupled controller is a combination of a (STATCOM) for regulating the voltage and an electronic load controller (ELC) for controlling the power which in turn maintains the system frequency constant. Again here a STATCOM is realized using IGBT and VSC.

In July 2008, Singh, Kasal, Chandra, and Haddad [14] proposed an investigation on a voltage and frequency controller (VFC), which functions as an improved electronic load controller (IELC) for parallel operated isolated asynchronous generators (IAGs) in an autonomous micro hydro power generation system. In such type of micro hydro scheme whole generating system is isolated from the grid and supply electricity to the remote communities. The single point operation of these generators is realized, in such a manner that excitation capacitors, speeds, voltage, currents of generators remain constant under various operating loads conditions. The proposed controller consists of a 3-leg IGBT (Insulated Gate Bipolar Transistor) based voltage source converter (VSC) and a DC chopper with an auxiliary load at the DC bus of the VSC. The IELC controls the reactive and active power simultaneously for controlling the voltage and frequency under varying consumer loads.

In October 2008, Singh and Rajagopal [15] proposed the synchronous reference frame for islanding Pico hydro system. The IAG system with ELC provides a viable and cost effective solution to achieve power quality improvement, voltage and frequency control, harmonic elimination and load balancing for feeding nonlinear loads.

In October 2008, Murthy, Bhuvaneswari, Gao, and Gayathri [16] described the analysis of dynamic and steady state performance of a self excited induction generator (SEIG) with digitally controlled electronic load controller (ELC) feeding single phase loads. The excitation capacitors, electronic load controller, 1-phase load in conjunction with the d-q model of the 3-phase induction machine taking into account the saturation effect are used to predict the dynamic behavior of the SEIG. The digital control is realized by means of PIC18F252 microcontroller which provides a better performance and suitability.

In November 2008, Kasal, and Singh [17] proposed a decoupled voltage and frequency controller (DVFC) for isolated asynchronous generator (IAG) used in pico hydro power generation for feeding 3-phase, 4-wire loads. The decoupled controller is a combination of a static compensator (STATCOM) consisting VSC with zigzag transformer for regulating the voltage and an electronic load controller (ELC) for controlling the active power which in turn controls the system frequency constant. The STATCOM is realized using IGBT (Insulated Gate Bipolar Junction Transistor) based current controlled voltage source converter (CC-VSC) and a self supporting DC bus.

In December 2009, Singh, and Rajagopal [18] developed an integrated electronic load controller (IELC) for an isolated asynchronous generator (IAG), used in constant power Pico hydro power generation for feeding three-phase four-wire loads. The IELC is realized using a star/delta transformer and three-leg insulated gate bipolar transistors (IGBTs) -based current controlled voltage source converter (VSC) with a DC capacitor, a chopper switch and an auxiliary load. The proposed IELC is used to control the voltage and frequency of IAG in integrated manner. The proposed IELC with the generating system is modeled and simulated in MATLAB along with Simulink and simpower system (SPS) toolboxes. The simulated results are presented for the IAG with IELC for feeding three-phase four- wire linear/nonlinear (balanced/unbalanced) loads with the neutral current compensation to demonstrate its performance.

In August 2010, Singh, Rajagopal, Chandra, and Haddad [19] proposed a decoupled electronic load controller (DELC) for an isolated asynchronous generator (IAG), used in constant power pico hydro power generation for feeding three-phase four-wire loads. The proposed DELC is used to control the voltage and frequency in the decoupled manner. The proposed decoupled electronic load controller is combination of a voltage regulator (VR) for regulating the voltage and a conventional electronic load controller (ELC) for regulating the active power (i.e. frequency). The VR is realized using a star-delta transformer and H-bridge current controlled voltage source converter (VSC) with a capacitor on its dc bus and an ELC is a combination of a three phase diode bridge rectifier with a chopper switch and an auxiliary load. The proposed electronic load controller with the generating system is modeled and simulated in MATLAB along with Simulink and power system block set (PSB) toolboxes. The simulated results are presented for three-phase four-wire linear/nonlinear loads with the neutral current compensation to demonstrate its performance.

In October 2010, Mahato, Singh, and Sharma [20] described the transient analysis of a three-phase self-excited induction generator (SEIG) feeding single-phase inductive load with an Electronic Load Controller (ELC) used in standalone micro-hydro power generation employing uncontrolled turbines. A complete mathematical model of the total system has been developed. The dynamic model of the SEIG using a three-phase star-connected induction machine is developed based on stationary reference frame d-q axes theory, with three capacitors connected in series and parallel with the single-phase load. Simulated results are compared with the experimental ones, obtained on a developed prototype of an SEIG-ELC system for the different transient conditions such as sudden application of load, sudden removal of load to validate the effectiveness of the proposed approach.

In October 2010, Rajagopal, Singh, and Kasal [21] proposed an implementation of an instantaneous reactive power theory-based electronic load controller (ELC) for regulating the voltage and frequency of an isolated induction generator system (IG) that can supply electricity in remote areas. This ELC provides the fundamental reactive power and compensates harmonics of load currents. The proposed ELC is a combination of voltage source converter (VSC) with a dc link capacitor, a chopper and an auxiliary load at its dc bus. The proposed IG along with its ELC is implemented on a 3.7 kW IG system.

In December 2010, Rajagopal and Singh [22] developed an electronic load controller (ELC) for a standalone induction generator (IG) used in small hydro power generation. This ELC is realized using a non-isolated T-connected transformer and three-leg insulated gate bipolar transistors (IGBTs) based current controlled voltage source converter (VSC), a capacitor, a chopper switch and an auxiliary load on its dc bus. The proposed ELC is implemented on a prototype of 3.7 kW 50 Hz IG. Test results of IG-ELC system are presented to demonstrate its performance for feeding three phase four-wire loads with the neutral current compensation.

In December 2010, Singh and Rajagopal [23] proposed a neural-network (NN)-based integrated electronic load controller (IELC) for an isolated asynchronous generator (IAG) driven by a constant-power small hydro uncontrolled turbine feeding three-phase four-wire loads. The proposed IELC utilizes an NN based on the least mean-square algorithm known as adaptive linear element to extract the fundamental component of load currents to control the voltage and the frequency of an IAG with load balancing in an integrated manner. The IELC is realized using zigzag/three single-phase transformers and a six-leg insulated-gate bipolar-transistor based current-controlled voltage-source converter, a chopper switch, and an auxiliary load on its dc bus. The proposed IELC, with the generating system, is modeled and simulated in MATLAB environment using Simulink and Simpower System toolboxes.

In January 2011, Rajagopal and Singh [24] described an implementation of an electronic load controller (ELC). It is basically proposed to the countries which has high end rainfall associated with it.It regulates voltage and frequency of the small hydro plant, Besides this the ELC balances the IG system under unbalanced loading conditions and eliminates the harmonics of the loads thereby acting both as a load leveler and a harmonic eliminator. The proposed IG along with its ELC is implemented on a 3.7kW system using a DSP.

In June 2011, Serban, and Marinescu [25] presented an aggregate load-frequency controller for an autonomous micro grid (MG) with wind and hydro renewable energy sources. A micro-hydro power plant with a synchronous generator (SG) and a wind power plant with an induction generator (IG) supply the MG. Both the systems supplies the power in to the grid making the system more robust and also its control method, which is based on a combination of smart load (SL) and battery energy storage system (BESS). SL and BESS provides the active power balance for various events that such systems.

In 2015 Shailendra Kumar Rai, O. P. Rahi, Sunil Kumar[26] proposed a theory which deals with use of an ELC for synchronous generator of micro hydro power plant of rating 60 KW in MATLAB Simulink. The design of ELC using a controlled bridge rectifier and IGBT chopper feeding a resistive dump load has been implemented for simulation in this paper. The power consumption of chopper has been varied by the duty cycle of the chopper. The simulation results have shown the changes in various parameters, i.e., excitation voltage, stator current, mechanical power output, output power of generator, power across consumer load, and dump load as a result of the change in demand/load.

In 2016 Murari Lal Azad, Sunil Singh, Atul Kumar[27] proposed a new Electronic Load Controller For MHPP which is proposed to have a reduced cost . This paper describes the requirement and concepts of Electronic load controller (ELC) and Induction generator controller (IGC). This paper describes the resent technology which can make very small schemes viable. Various Electronic controllers are discussed for induction generators as well as alternators. its pros and cons is described and economically viable system is suggested for the system below 30kw capacity

III. DISCUSSION

This paper presents the extensive review of the work and the progress in the area of design development and recent innovation in the field of Electronic Load Controllers. It has been observed that various Electronic Load Controllers are working efficiently and the dump power is dissipated in the form of heat to maintain the operating point of the system constant. Also it has been found that a lot of work can be done to make that dump load power to be utilized in any form like water heating, lighting or even for voltage correction using as a source. It can also be utilised for charging the battery and further can be utilised for any suitable purpose. In case of a synchronous generator it can be utilised even for excitation systems. So a lot of area and scope is there which is unexplored.

IV. CONCLUSION

This paper presents an overview and key issues of different research studies in the area of Electronic Load Controllers. It is clear, from the existing literature, that there are different solution methods for switching techniques for dump loads. This paper describes step by step development in the area of Electronic Load Controllers and many methods to utilise the dump loads which provides relevant guidelines and references for the researchers intending to do additional study in the area Electronic Load Controllers.

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