Mathematical Model Approach for AC and DC Regulators Excitation Systems (ES)

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Abstract. Balancing equations for excitation system is very basic and fundamental concept and in some cases it becomes more difficult so that a mathematical treatment is needed in order to make it easy for AC and DC Regulators Excitation Systems (ES). This research paper mainly focuses on an excellent application of The power generating units and higher power motors are majority included by wound field synchronous machines because of it has flexible field excitation, flux intrinsic weakening capacity and high efficiency. It can be also used in low to medium power range for high end solutions in a wide range. This paper is analyzing a study of modern methods and technologies of excitation system for AC and DC regulators.

Keywords: Excitation systems, SM, SES and BES

1. Introduction

In the power generation units or applications a wound field synchronous motors are preferred from the range of few kVA leading in grid connection systems and small to medium applications in regulations. The main merits of this machine are robustness, capability of power factor control, used in control the reactive power flow, increased air gap, reliability with overload handling capacity and its high efficiency [2]. Moreover in high power applications the wound field motors are mainly used in oil and gas industry. It has the several merits and benefits while compared with permanent magnet synchronous motor.

Basically, the WFSM winding is powered by three methods: i) brushless exciter ii) slip rings and iii) rotating transformers [1]. After that the brushless system is developed to provide power to field winding. Here the transformer and brushless exciter are essential in part of system size and weight. Normally the excitation is the providing current to field winding with control and productive elements. Now days the methods of static excitation in that shaft slip rings and brushes are providing power to field winding is preferred during the requirement of dynamic response [3, 15]. At the mean time, due to possible sparking and brush wear, the safety problems and maintenance are caused in the system but a brushless motor can overcome these problems because of electromagnetic induction is supplied power to field winding without sliding contacts. In the worst dynamic response case, the exciter installation is to be over the generator for safety purposes. The power electronics based devices are
used to control the system current and measurement of field winding through the wireless communications the exciter issues are overcoming and excitation current is regulated[4,5].

2. Static Excitation System
The excitation system is (ES) based on the dc exciters and a dc source is supplied to the exciters by an isolate motor and the current to field windings are done by slip rings. The dc excitation system is classified into three types: Static excitation system (SES), Brushless excitation system (BES), Embedded excitation system (EES).

2.1. Static Excitation System
In this system, the dc supply is fed to field winding from generator and here all the components in the systems are static. The rectifier in the system is powered by the main generator to the process of rectification. For example twelve switches of two six MOSFET bridge network is connected in parallel for the field winding circuit. One of them in active state which means it conducting excitation current to field winding and another one bridge is reserved. If any fault occurs in the system the active bridge is disabled and the reserved bridge comes to act without any manual involvement. Normally the static excitation system is classified into

2.2. Booster Excitation
This system is planned to improve the fault ride through (FRT) capability and the booster excitation (EB) is represent in fig.1 and it is divided into two categories respect to its ability to raise field voltage during the fault occurrence. In these types, the first one is provides signal to the excitation system reference voltage while the second is supporting the excitation system with a back up of additional source [7,8,9]. In the disturbance period, the first category is using remote measurement for control system elaboration and transient excitation booster is also using measurement of remote to provide pulse for the reference of the excitation. The second type is enhancing the excitation to field through an additional voltage or current source.

![Figure 1. AC excitation systems using DC and AC regulators.](image)

The static excitation system with the configuration of buck-boost chopper is to get the solution of low voltage grid conditions and solve the potential system’s forcing capability. By using the scheme of boost-buck excitation (BBE), the provision of chopper output can always maintaining the direct current (DC) link voltage in case of the supply or terminal voltage is reduced [8,10,14]. But the chopper BBE can done it with the help of DC link capacitor and the excitation system is protected from the sudden failure of the power supply due to the transients and over voltage as well. In fig. 1 the
AC excitation systems using DC and AC regulators are represented. The power semiconductor devices can be used at the configuration of BBE and the turn on and off process are done at any instant by adjusting the firing angle or the delay angle. Firing angle is represented by the converter can provide any power that available to the ES [11,13].

3. Embedded Excitation Systems

The components used in exciter are integrated and placed at the main stator of the WFSM where the embedded excitation system is an alternative exciter less and the recent solutions are. It is a classical ES method, the harmonic single phase winding in the machine stator is producing the excitation current to the field winding and the electro motive force is induced by the field rotating air gap harmonics. It is sufficient to provide enough current to the rotor winding along with bridge network of 4 pulses SCR using the slip rings as well as carbon brushes. New winding of stator harmonic is added to supply for the WFSM with the full excitation power. It increases the WFSM. Rotor Harmonic In this system, to supply the excitation power to the field winding the damper rotor slots are utilized for the single phase circuit connected with the rotor. The single phase auxiliary winding is supplying the current to the DC link capacitor through the conversion stage using boost converter. This voltage from the conversion stage is fed to the field winding of the WFSM. This is being analysed by using mathematical modelling as

4. Modelling Embedded Technique Excitation

The conjugate gradient method can theoretically be viewed as a direct method, as it produces the exact solution after a finite number of iterations, which is not larger than the size of the matrix harmonics can be analyzed, in the absence of round-off error. However, the conjugate gradient method is unstable with respect to even small perturbation. Figure 2 gives the output results of AC excitation systems using DC and AC regulators with different loads, most directions are not in practice conjugate, and the exact solution is never obtained. Fortunately, the conjugate gradient method can be used as an iterative method as it provides monotonically improving approximations \( x_k \) to the exact solution, which may reach the required tolerance after a relatively small (compared to the problem size) number of iterations [7-9]. The improvement is typically linear and its speed is determined by the condition number \( k(A) \) of the system matrix \( A \): the larger is \( k(A) \), the slower the improvement.

If \( k(A) \) is large, preconditioning is used to replace the original system \( Ax = b \) with \( M^{-1}(Ax - b) = 0 \) so that \( k(M^{-1}A) \) gets smaller than \( k(A) \).

Convergence theorem: Define a subset of polynomials as \( \pi_k = \{ p \in \pi; p(0) = 1 \} \), where \( \pi_k \) is the set of polynomials of with highest degree \( k \). Let me defined the error as \( e_k = x_k - x \). Let \( (x_k) \) be the iterative approximations of the exact solution \( x \).

Proof:

\[
\|e_k\|_A = \min_{p \in \pi_k} \|p(A)e_0\|_A \leq \min_{p \in \pi_k} \max_{\lambda \in \sigma(A)} |p(\lambda)| \|e_0\|_A \leq 2 \left( \frac{k(A) - 1}{\sqrt{k(A) + 1}} \right)^k \|e_0\|_A, \tag{1}
\]

Where \( \sigma(A) \) denotes the spectrum and \( k(A) \) denotes the condition number. Now let us take the limit as \( k(A) \to \infty \) i.e.,

\[
\lim_{k(A) \to \infty} \left( 2 \left( \frac{\sqrt{k(A) - 1}}{\sqrt{k(A) + 1}} \right)^k \|e_0\|_A \right) = 2\|e_0\|_A. \tag{2}
\]
Because, 
\[
\frac{\sqrt{k(A)} - 1}{\sqrt{k(A)} + 1} = \frac{1 - \frac{1}{\sqrt{k(A)}}}{1 + \frac{1}{\sqrt{k(A)}}} = 1 - \frac{2}{\sqrt{k(A)}}, k(A) \gg 1.
\]

Thus, this limit conveys conjugate gradient iterative method is faster convergent.

![Figure 2. AC excitation systems using DC and AC regulators with different loads.](image)

5. Conclusion
High voltage gain is achieved based Cockcroft Walton voltage multiplier has three stages and also produces continuous current with low ripples without use of transformer is presented in this paper. Regulation of output voltage is obtained by controlling the duty ratio of controller excellent application using mathematical modelling of the power generating units and higher power motors are majority included by wound field synchronous machines because of it has flexible field excitation, flux intrinsic weakening capacity and high efficiency. It can be also used in low to medium power range for high end solutions in a wide range. Less number of stages with ac and dc regulation being successfully is achieved in this paper. Proposed converter and its output results are verified through MATLAB/ Stimulant. Converter will analyze the steady state and to increase the voltage and reduce the size of passive device in future.

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