# Excitation Systems (ES) for Wound-Field Synchronous Machines (WFSM)

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## Abstract

The power generating units and higher power motors are majority included by wound field synchronous machines (WFSM) 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 WFSM excitation system. This paper also explains that the trending excitation system of generators and WFSM excitation system.

**Keywords:** Excitation systems, WFSM, SES, BES.

## 1. Introduction

In the power generation units or applications a wound field synchronous motors are preferred from the range of few kVA. The WFSM is leading in grid connection systems and small to medium applications. 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 of WFSM. 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]. 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.

## 2. Excitation Systems

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:

i) Static excitation system (SES)

ii) Brushless excitation system (BES)

iii) Embedded excitation system (EES)

## 3. 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. Fig.1 shows the EB in the excitation system of the bus supply. Normally the static excitation system is classified into

### A. Booster Excitation

This system is planned to improve the fault ride through (FRT) capability and the booster excitation (EB) is represent in fig.2 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 [6-7]. 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.

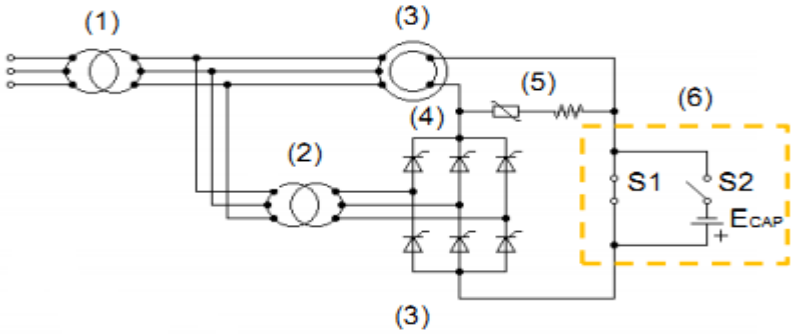


**Figure. 2 Excitation Booster of Bus Supply ES**

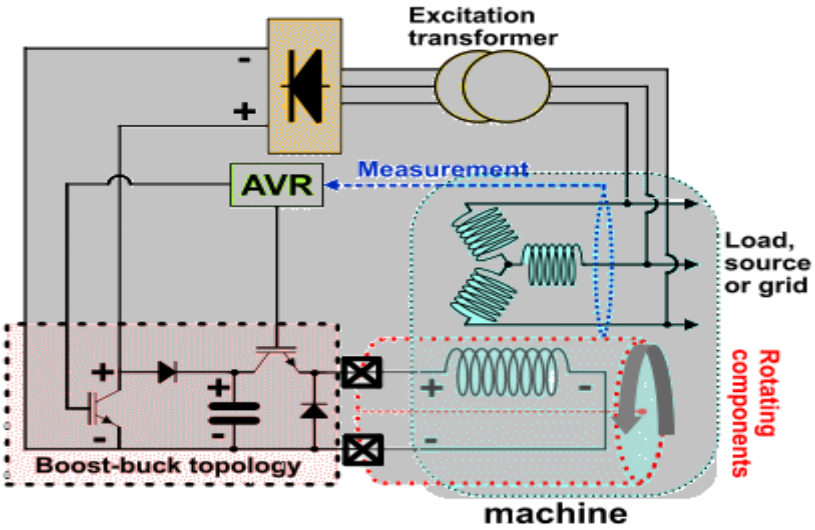


**Figure. 2 Boost Excitation Systems**

### B. Boost-Buck Excitation

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]. 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. 3 the AC excitation systems using DC and AC regulators are represented. The power semi conductor 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 [9-10].

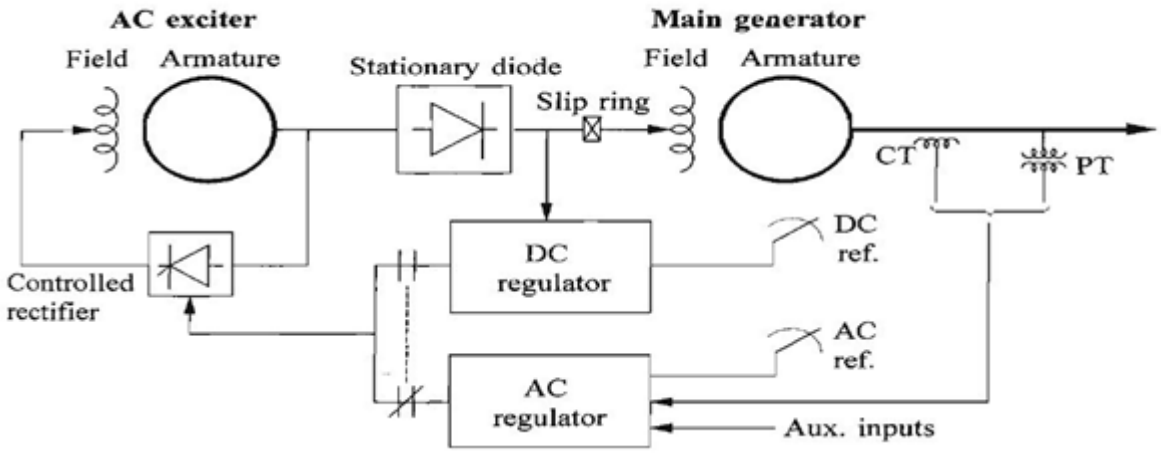


**Figure.3 AC excitation systems using DC and AC regulators**

## 4. Brushless Excitation System

To supply the current to the machine without using brushes and the slip rings is called as a method of brushless excitation system. From this, the system has no brushes due to the resistance in the carbon brushes. This system consists of two main exciter systems as following main and pilot exciter. The electromotive forces are induced by the air-gap that of main and the current is fed to the WFSM rotor field. Here the uncontrolled rectifier is fixed on the machine that rectifying the AC supplies current to the DC for rotor [4]. The recent methods are explained as below,

### A. Rotating Transformer

In the vehicle applications the rotating transformer (RT), shown in fig. 4 is excited system for the purpose of producing a high torque and the efficiency improvement [5]. This RT has single phase rectifier with the four diodes and using switches for the winding excitation. By this transformer with high frequencies directs to the wireless power transmission as well as the compactness benefit.

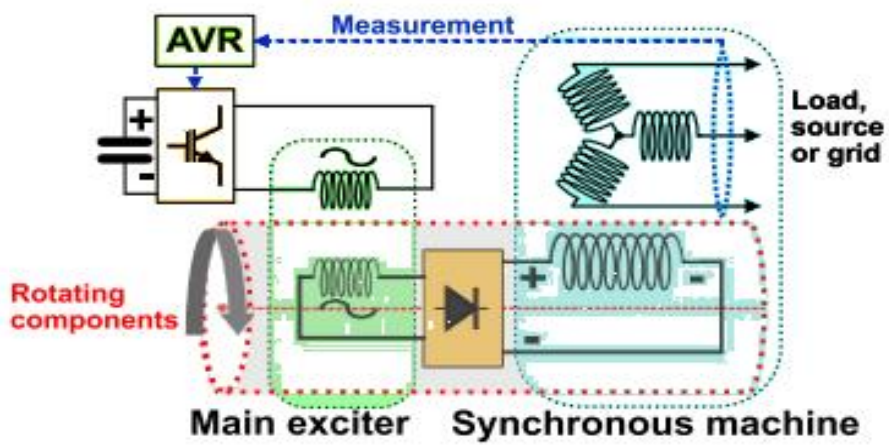


**Figure. 4 Rotating transformer**

### B. Shunt Hybrid

A hybrid excitation is presented to overcome the constraints of the shunt hybrid excitation system without the isolate permanent magnet generator (PMG). To provide the power which is appropriate for machine excitation, the permanent magnets are mounted on the stator at its no load operation. Along with this method, the system modifying are not necessary to both generator as well as exciter circuit. In WFSM, there is loss o field can be minimized at any conditions by using the typical solutions and the PMs provide the operation with continuously during the fault as well as transients voltages in the field exciter winding. In this method the overall efficiency of the system as well as the reliability can be improved. The shunt hybrid system is shown in fig. 5.

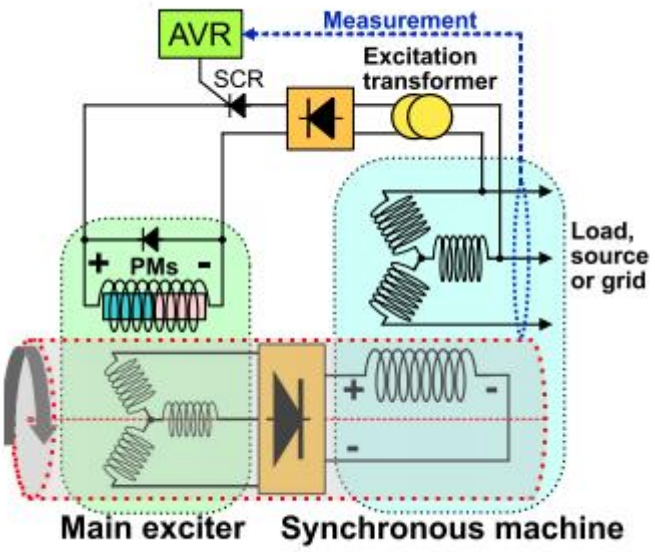


**Figure. 5 Shunt hybrid systems**

## 5. 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,

### A. Stator Harmonic

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 [11]. 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.

### B. 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.

## 6. 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. The gain of the CWVM is high while compared to the existing two stage converter. Single stage output voltage is 270V and it is same to the remaining stages, and overall output voltage of the system is 800V. Less number of stages with high voltage gain is achieved in this paper. Proposed converter and its output results are verified through MATLAB/ Simulink. Converter will analyze the steady state and to increase the voltage and reduce the size of passive device in future.

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