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ELECTRODYNAMIC Solutions

Modern Electronic Solutions for Vintage Vehicles

# Electronic Dynamo regulators demystified.

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## Introduction

Love them or hate them but the one thing that most cars built before 1975 have is a dynamo generator to supply the vehicles electrical needs. Dynamo's have been used in cars since the 1920's in various forms. Early devices used fixed magnets to generate the "field" in which the armature rotated in to convert the rotary mechanical work to electricity. Very soon these became electromagnetic field coils which allowed the output voltage to be controlled – hence the need for a dynamo regulator.

Let's get back to basics, how does a dynamo work? A quick recap may help explain why there is not just one electronic regulator that "does all". First of all dynamo's are DC machines – what does that mean? It means that as the armature rotates (the bit connected to the pulley) the magnetic field from the field coils cuts the armature coils and induces a voltage in the windings producing a flow of current (think of voltage like the pressure of water in a hose pipe and the current as the volume per second flowing). However that voltage rises and falls and would reverse in polarity as the armature rotates were it not for the brushes and commutator that act like a set of switches making sure the current only flows in one direction – Direct Current or DC.

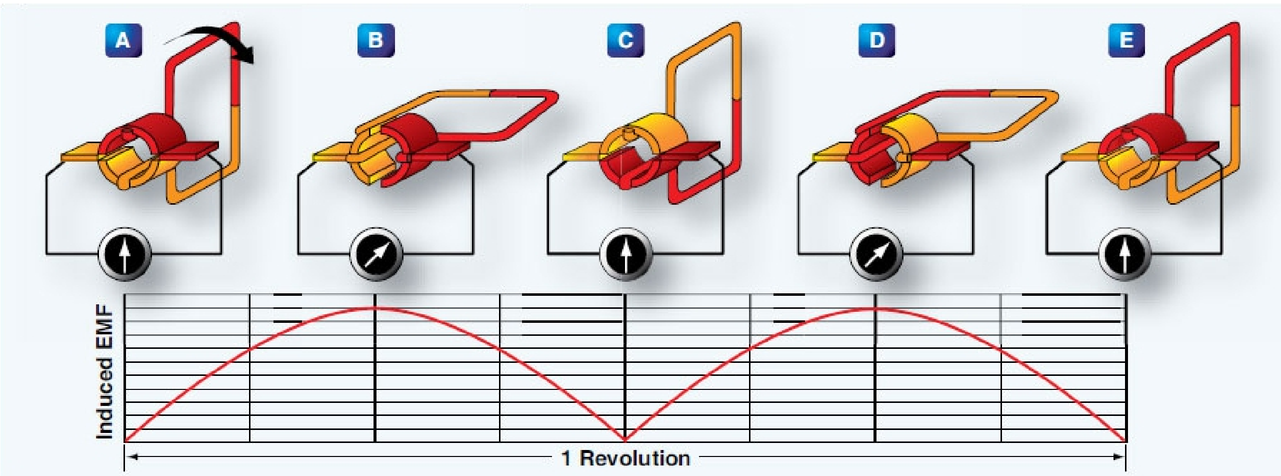


Figure 1. Basic action of commutation.

Now a dynamo is a bit like a pump with water – the faster it rotates the more the pressure (voltage) increases. Hence as engine speed increases so does the voltage and without some form of regulation the voltage would exceed the operating voltage (the battery voltage usually 13.2v on a fully charged battery) and pop all your bulbs and boil your battery. This is not usually recommended and viewed as a bad thing.

## The mechanical regulator

Enter the mechanical regulator. In essence it's a mechanical variable frequency variable pulse width modulation non return to zero switching regulator. Bet you did not think of that when you take the lid off and see a couple (sometimes 3) coils of wire. What are functions of those coils – let me explain as it relevant in some respects to electronic regulators as well.

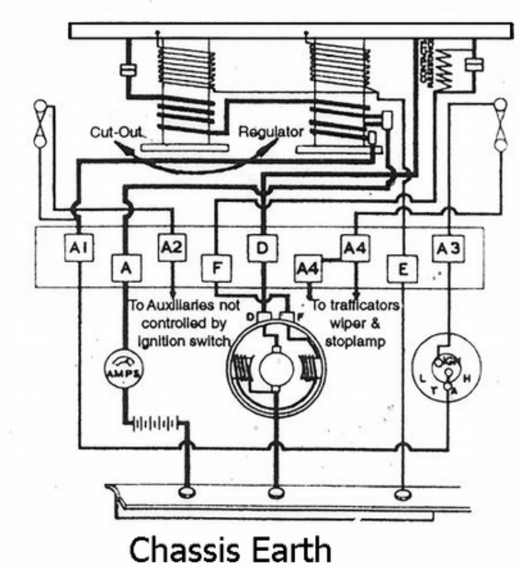


Figure 2: Mechanical wiring

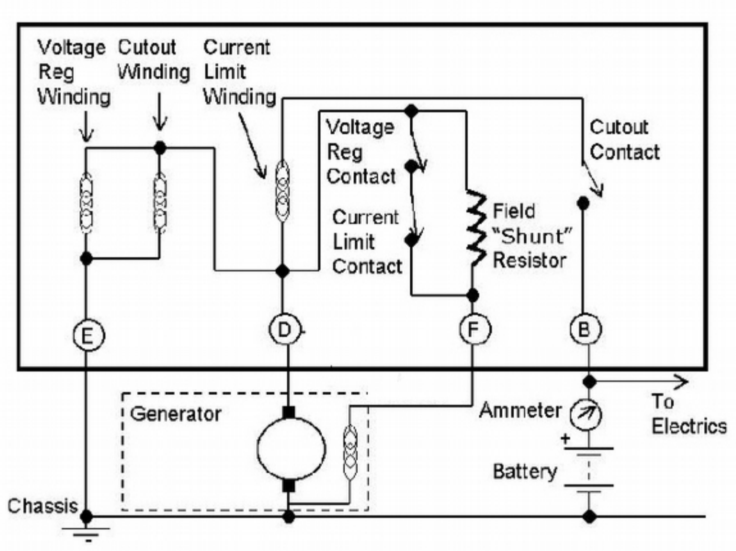


Figure 3: Electrical Equivalent

Figure 2 shows a typical 2 "bobbin" regulator where one bobbin has 2 functions and the other a single function. Figure 3 shows the electrical equivalent of the coils. Let's examine the functions of each of the coils. In a DC dynamo system there is no voltage output from the dynamo when it is stopped and only a low voltage when the armature is first rotated from the residual magnetism in the iron windings. Until the positive feedback from the armature to the field coils reaches "cut in" speed when the dynamo volts are above battery volts we need to keep the battery and load disconnected. As previously mentioned the dynamo output voltage is proportional to the engine speed so when there is no DC being generated what stops the battery from simply flowing current back through the armature winding of the dynamo. In essence it will become a motor and will happily turn and drain your battery!

To prevent this reverse current flow is the function of the cut out coil. It is simply an electro magnetic switch. The switch is normally open (off) and stops reverse current. Once the coil is energised it "pulls in" the contacts against a spring to close the switch. Looking at the diagram we can see that when the dynamo starts generating current this will flow through the cut out winding and the regulation winding. At some point the magnetic field becomes strong enough to close the cut out contact and allow current to flow into the vehicle loads and the battery. The point at which this occurs is set on the screws that balance the spring pressure again magnetic pull in and is set to "cut in" once the generator voltage is above that of the battery. When the engine slows and dynamo volts drop, spring pressure will overcome the magnetic field and open the cut out disconnecting the battery and vehicle loads from the dynamo to prevent reverse current flow.

The other coil has a dual function (in some sets ups there are 2 coils one for each function). In the same manner as the cut out, current flowing through the coil produces a magnetic field to open and close a switch contact that provides current to the field coils. The field coils are electromagnets producing the magnetic field in which the armature rotates in order that mechanical rotation is turned into electricity. But why do we need the switch – simply because without it the field current will allow the dynamo to generate too high a voltage as the revs increase. The coil "senses" the voltage (actually it's the current flow through the coil proportional to the voltage developed across the coil inductance and resistance) and when it reaches a limit the switch opens and the field current flows through a series limiting resistance which reduces the magnetic flux strength and hence the dynamo output voltage falls until a lower limit when the switch closes again to increase the field current. This process repeats 30 -60 times a second and gives the "buzz" that can be heard on the contacts.

There is another winding on the same coil – it sense's the current flowing between the dynamo output (the D terminal) and the battery and vehicle loads. As you can see from figure 2 it can not sense current flow until the cut out has connected the dynamo to the vehicle loads. Dynamo's will produce as much current as the rev's will allow them to dependant on vehicle load. With a flat-ish battery on a cold morning with the lights, blowers and wipers on the dynamo could be overloaded and try to drive to much current – resulting in burnt out armature coils. Hence the current limit coil which uses the field control current to limit the amount of load current the dynamo can produce.

So that is a simplistic description of what a dynamo regulator has to do – its actually a lot more complex as the regulator and dynamo are part of a feedback network where the dynamo inductance, coil resistance, rotation frequency along with the mechanical characteristics of the regulator switches springs and bimetallic elements and the temperature and vehicle loads all contribute to the switching frequency and hence the regulation characteristics.

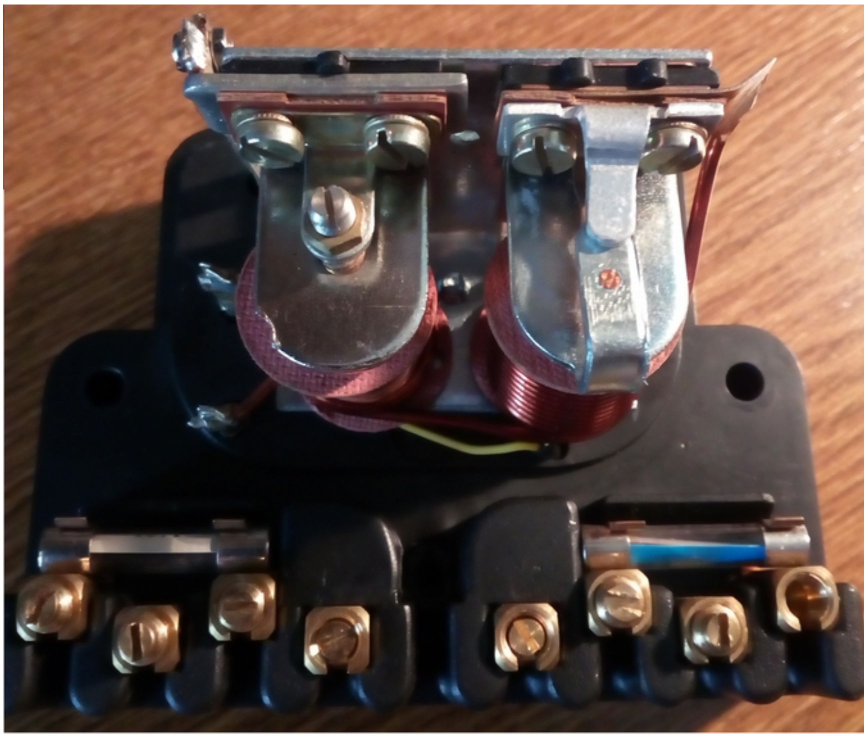
Figure 4 Electro Mechanical Regulator

## Electronic regulation – the challenges.

After I graduated with a degree in Electronic engineering I worked for Lucas Industries, hence I gathered a lot of useful knowledge on automotive systems and their requirements. Later on in my career I became a chip designer for several large American Semiconductor companies and developed devices for the automotive industry including a "knock sensor analogue processing chip" that sold all over the world for my old company Lucas ! Hence when I came to design an electronic version of the dynamo regulator I was well acquainted with the shortcoming of the current market offerings both mechanical and electronic.

As a classic care owner myself my introduction into the dynamo regulator field came as my 1953 Alvis decided to stop charging on a rally leaving me at the side of the road. Interestingly the AA man arrived with diagnostics tool in hand and I was able to point out to him that first all it needed was a battery and secondly there was no diagnostic port ! I went down the route of replacement mechanical regulator – bad idea – 6 months and a set of welded points and a dead battery made me think of alternates. That is how I got into manufacturing and supplying dynamo regulators.

The principle problems with mechanical regulators are as follows:

- Wear – being mechanical the pivot points and springs wear over time
- Points corrosion – when interrupting an inductive load a back emf produces a spark than erodes the contact material altering the gap and hence the set voltage
- Set up – adjustment is difficult as the coils heat up altering the set point.
- Tolerance – the coils resistance change with temperature as do the spring settings altering the voltage and current set point.
- After Market – Old Joe Lucas doesn't make them like they use to – in fact they don't make them at all and most of the replacements are of inferior materials and workmanship resulting in short lived operation. (there are a few British companies that are the exception) I have had many a story of welded cut outs !

On the plus side the mechanical regulator is relatively robust and able to survive sparking and arching caused by worn out commutators and wiring shorts – a common problem as vehicles age.

Enter the dynamo electronic regulator. Its basic function is much as the mechanical regulator thus:

- A cut out function to prevent the battery from discharging through the dynamo
- A voltage regulation function to control the dynamo output voltage.
- A current limit to prevent the dynamo from overheating.

In addition the electronic regulator should include the following features:

- A control circuit to hold the dynamo output voltage at a fixed level independent of time or temperature so as to provide current for electrical loads and the correct charging of lead acid batteries.
- A low cut in speed so the dynamo starts to produce charge as soon as the engine revs allow
- Spike protection against voltage transients
- Tight over current limit
- Mechanically robust against water and dirt
- Physically small enough to fit inside existing mechanical casings.
- Simple wiring and no adjustment requirement
- It should have low heat dissipation.

## Electronic regulators – what do you need to know beforehand

I get phone calls and email and read a lot on various forums about how "suitable" electronic regulators are for various types of dynamo. Quite often the question is along the lines of do you supply a regulator for a 1937 Morris van etc. The issue is I have not got a list of every type of dynamo fitted to every type of car, boat, and tractor and so on. So there are some basic questions that need to be asked – why? because the regulator I supply has to be suitable to the application. The things I need to know are thus:

1. Is it positive or negative earth – rather important as the circuitry for positive earth is different from that of a negative earth and they are NOT interchangeable!

2. What is the voltage of the battery? We manufacture regulators for 6 volt and 12 volt systems

3. Is it a 2 or 3 brush dynamo – older types have "summer" and "winter" switched brushes and have to be converted to a 2 brush before they can be regulated. We have a paper on how to do it.

4. What is the rated power of the dynamo or what current limit do you need. As high as you supply I get told – wrong! I will explain why later

5. What type of dynamo do you have – series or shunt wound? That again determines the internal circuitry of the regulator.

So as you can see so far we have 2 different earthing arrangements, 2 different voltages and 2 different types of dynamo, that along with a mydrid of different current limits means that no one electronic regulator is suitable for all applications. One size does not fit all. But saying that; we make a regulator to suit most applications including the ubiquitous dynastarts.

Let's examine points 4 and 5 in detail. As mentioned before dynamo's need a current limit. Quite often I get the question – I have a c39 Lucas dynamo therefore I need a 22 amp current limit as that's what the dynamo is rated for. True enough but consider this: A dynamo was rated to supply the full electrical load of the vehicle it is fitted to. How many classic car owners actually drive around with wipers, headlights, heater blowers, fuel pump and ignition all on at once – answer is probably very few if any. Most classics do not need the full rated output and importantly if you have converted to

LED lights that takes away about 6-8 amps of load. Another thing is most of these cars are over 50 years old, have shellac varnish on the dynamo windings that is sensitive to heat. More current, more heat more likely a failure. I usually recommend a current limit of about 80% or so of the rated output so as not to stress the old windings and this will still provide plenty of charge current in normal use.

The question in point 5 is important. Lets examine what is meant by shunt or series wound. This is also known as live side or ground side regulated.

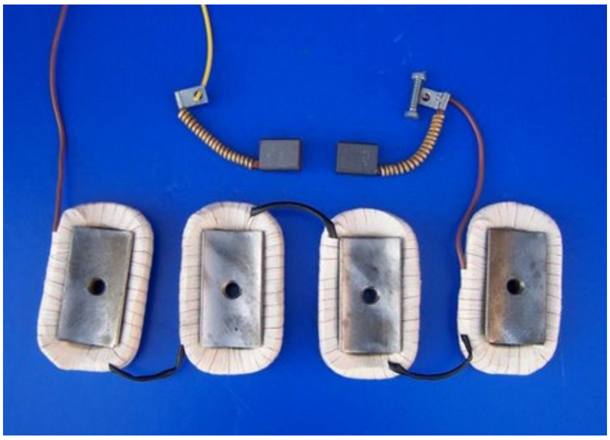

Figure 5 Shunt wound dynamo

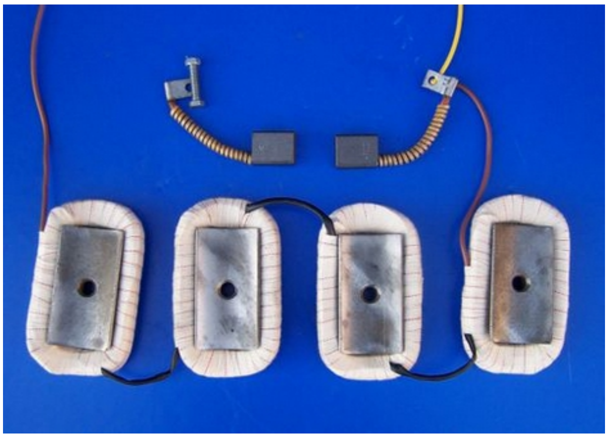

Figure 6 Series wound dynamo

Figure's 5 and 6 show the arrangement of the fields coils in the two types of dynamo. Shunt wound coils are ground side regulated. Following the wires in figure 5 shows the terminal post connected to the field coil and the brush, this is ground end that is connected to chassis earth. The yellow wire is the dynamo D output to the regulator. Field current flows down the green wire through the coils to earth from the regulator. This is typical of Lucas type dynamo's and our DVR3 range is designed for this configuration. The DVR3 controls the current flowing through the coils to earth and regulates the output voltage accordingly.

In figure 6 the brush on the left is grounded and the right hand brush is connected to the output yellow wire and the green field wire. Hence current flows to the regulator cut out from the yellow wire and also through the field coils and out of the green wire to the field control pin on the regulator. This is the DVR4 series of regulators. These control the current that flows through the coils then through the regulator to chassis earth. This is typical of Bosch type dynamo's and Dynastarts.

So when it comes to replacing your old mechanical regulator with a solid state one you need to know if you have a series or shunt wound dynamo, its rated power output, the battery voltage and the vehicle polarity positive or negative earth.

I have described how the old coil system worked in detail above. But how does an electronic regulator perform these functions? Let's delve into this and at the same time dispel a few myths that seem to make the rounds about electronic regulators.


DVR4 Electronics cut out, voltage and current regulator

From the time that semiconductors became available various parts of the vehicles were built with electronics instead of mechanical to improve performance and reliability. Think of the transistor aided ignition to reduce contact burn on points, then contactless ignition using optical and hall effect sensors through to full IDI and CDI ignition systems and now full engine management computer controlled individual coil ignition. Well with dynamo regulators the originals were a big improvement on mechanical coils but used bipolar transistors and diodes for the switching functions. These produced a lot of heat and hence early regulators were bulky and needed a heat sink. This is myth number 1. Yes there are a few people still using blocking diodes for the cut out but not us. We use a power mosfet as the switch with such a low on resistance that the wires connecting the regulator have higher resistance than the mosfet when its conducting. Hence even passing 22 amps of current our regulator cut out produces less than 1 watt of heat. There are people in the market who claim to have the lowest heat dissipation – they don't. Most of the heat is generated in the control transistor that switches the current on and off for the field coil. In general the higher the power of the dynamo the more field current is needed and the more heat is generated. However we use a custom thick aluminium case which, if attached to the old coil bracket will be more than adequate to allow the unit to sit inside the old housing.

Myth 2 – electronic regulators can't be adjusted. Well Yes and No. Some designs on the market use a potentiometer to allow adjustment. Ours don't. Why because there is absolutely no need to adjust anything as it never goes out of adjustment. The design uses an internal reference voltage known as a band gap reference (old design's used a resistor ladder with a couple of diodes which drift with temperature) to set the output voltage that it regulates at. It is stable to within 0.2% over -20 to +85 degree's. Hence it sets the dynamo output to a stable 14.2 volts which is the optimal for lead acid battery charging over a standard 5 to 30 degree temperature range. This is not optimal for all cases of lead acid battery charging as depending on the state of charge of the battery and the battery temperature the charging voltage should change but it's a good compromise and will not overcharge the battery. Potentiometers are electromechanical devices – they don't like heat or vibration or dirt or moisture. There is no reason to use one in a properly designed regulator.

The third myth is around the current limit on the regulator. Recall from the description above regards the mechanical regulators using a current sense coil to limit the field if the dynamo was pushing to much current. Our electronic regulator does them same type of control: backing off the field current to control the output current. Early designs used operational amplifiers and transistors to set the current limit by measuring the current through a series sense resistor. These needed to be relatively large resistances due to the problem with offset voltages and hence produced a lot of heat and were lax in their set points. They also needed to have the resistance in the ground lead. Our designs use a series sense resistor but of such low value that it dissipates less than ½ watt. We can do this as we use high side current sensing with special amplifiers that are so accurate that we can set the current limit to +/- 1 amp over the full temperature range.

Another myth is the reliability. Yes electronics is susceptible to the harsh environments of the automotive world. Early and other design use standard commercial parts. We do not. Our designs use only automotive qualified parts that meet standard AEC-Q101. These are rated from – 40 to +125 operating temperature. We also pot our design in a 2.5mm thick aluminimum case with high temperature resin to exclude contamination and hence can be used in damp or salt water environments without degradation. The design also incorporates clamp diodes on our field control transistor to control back emf when regulating and to reduce radiated EMI.

Our biggest issue with reliability is incorrect and/or live connections the regulators are fairly tolerant but can only function correctly when matched to the application and installed in a manner as detailed in the data sheets. Connecting wires when the battery is installed or removing wires when the engine is running is going to result in large transients that can damage electronics. (In the automotive industry we design things against what is known as "load dump") There are transient suppression diodes to clamp voltage transients (as can be caused by sparking brushes for example) but the optimal solution would be to ensure you have installed the regulator in a sturdy electrical manner and have a good dynamo to start with. We often recommend a dynamo overhaul if a vehicle is rebuilt as it's a false economy to not do so and expect reliability. Only last week a client reported a failure with an installed system to me and when examined it turned out the dynamo bearing had seized and killed the dynamo – our regulator worked perfectly after he had the dynamo rebuilt!

One other point on dynamo's – they rely on the residual magnetic field in the iron core to get started before the electromagnets of the field coils can do their thing and generate the field. Sometimes this residual field can become weak – especially if the dynamo has not been used for a long time and stored in a manner where the earth magnetic field can polarise the iron windings. So the solution is to "flash" the dynamo – This involves momentarily connecting the Field windings between the live battery terminal and ground causing a large transient current to flow and remagnatise the iron core. NEVER EVER do this with anything connected to the dynamo – the large transient current and resultant back EMF will kill anything electronic connected to the dynamo.


Typical installation of a DVR3 into the existing housing

The final point is in regards to the aesthetics of an electronic solution. We are electronic engineers who design regulators. In order to keep the cost affordable these units are designed to be fitted by the average enthusiast. There are companies that offer a fitting service to put their regulator into the old housing. Fine but that pretty much doubles the cost. However to make the job easy the key questions have to answered first by the enthusiast. Fitting is easy if the correct part is specified in the first instance. So if you are thinking of fitting an electronic regulator these are the sorts of questions to ask first.

1. Is the vehicle positive or negative. A lot of pre war was positive earth but a lot of market add on's need negative earth (GPS for example or a radio). Are you using a 6 volt or a 12 volt electrical system?

2. Does the dynamo need a rebuild? If you do nothing else at least replace the brushes and clean the commutator with alcohol to prevent sparking.

3. What power do I need from the dynamo – remember old dynamo's are somewhat fragile due to the shellac insulation and if you only use your classic on a summer's day then you don't need full rated power.

4. If you are the proud owner of a vintage vehicle with 3 brush (summer/winter) dynamo then you will need to convert it to a 2 brush (instructions on my website) before you can use an electronic regulator.

5. What is the field coil resistance? For our regulator it can not be less than 2.8 ohms as that dictates the maximum field current we can carry, usually its 5 to 13 ohms.

6. Do you have a dynastart, no problem we can regulate them but you will need a separate high current solenoid to carry the starter current.

7. Remember that to use an electronic regulator you have to remove ALL of the old parts from the old housing if you are going to mount it in that housing. This includes the old coils and the wire would field resistor on the back of the unit.

In conclusion: There are a lot of myths around switching from a mechanical regulator to an electronic regulator. Most of these myths are hearsay and are wrong. There are many advantages to switching to an electronic solution but the solution chosen has to be carefully selected to make sure it fits the application. This article should have shone some light on the questions to ask before choosing a regulator and demystified their operation. Our website www.electrodynamicsolutions.com has various articles and papers that will assist you in testing a dynamo, converting from a 3 brush and choosing the correct part.