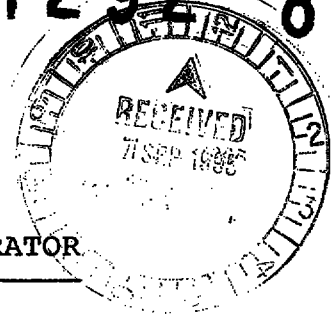


9501292-8

- 1 -



BICYCLE LIGHTING SYSTEM AND GENERATOR

The invention relates to a bicycle lighting system comprising a dynamo system drivable by a ridden bicycle and mounted thereat, at least one front-light, at least one rear-light, which in each case are supplied with electric power from the dynamo system, and a converter arrangement which converts the electric power produced by the dynamo system into a regulated direct-current voltage for generating light and charging an accumulator battery. The invention also relates to a generator for general applications, particularly however for use as a bicycle dynamo system.

Conventional and marketable bicycle lighting systems have to comply, with respect to the electric power and voltage, with the standards determined by law. These standards specify a maximum voltage of 7 V for the output voltage of the dynamo applied to the lamps at 15 kmph and beyond such speed. In accordance with legal regulations, the minimum value of the dynamo output voltage must not fall short between 5 kmph (3 V) up to 15 kmph (5.8 V) and beyond such speed (refer to Figure 5a). On the basis of these legal regulations, present-day systems allow producing merely 1.4 W power at a traveling speed of 5 to 6 kmph. If one would increase this power of present-day conventional dynamos, it would be physically impossible to meet or observe at 15 kmph or beyond such speed the legally specified maximum voltage of 7 V. Only by means of load measures would it be possible to prevent exceeding the legally specified maximum values. As a result of this, the power dissipation would greatly increase and the efficiency would considerably decrease.

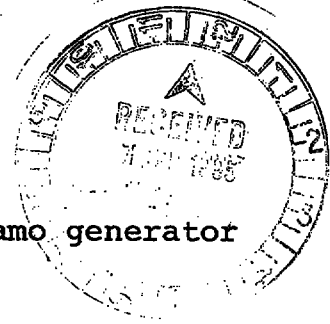
Therefore, conventional bicycle lighting systems are not additionally loadable in the lower speed range for the purpose of charging an accumulator battery. Only starting from a traveling speed of approximately 15 kmph, conventional dynamos will generate sufficient power that could be utilized for charging an accumulator battery, because the efficiency of conventional systems is very low at a speed below the aforementioned traveling speed of 15 kmph (side dynamos have an efficiency of approximately 17% to 24%, roller dynamos 30% to 35% at the most, and hub dynamos an efficiency of about 40%). When the traveling speed exceeds 15 kmph, the efficiency additionally decreases because of the power consumption while charging the accumulator battery. As a result of this fact, the bicycle rider is obliged to expend additional physical energy for the actuation of the dynamo.

Those skilled in the art have found fault with this fact and have realized that the conventional dynamos and bicycle lighting systems do not correspond with the state of present-day know-how.

Therefore, it is an object of the invention to provide - in combination with a generator - a bicycle lighting system which is adapted to the state of present-day technology and modern requirements and which, moreover, should be an economically favorable solution.

A further object of the invention is to provide a dynamo system which - with regard to construction, power efficiency and production cost thereof - meets the requirements of the bicycle lighting system according to the invention.

To implement the aforesaid object, the present invention is based on the conclusion that a satisfactory bicycle lighting



system can only be realized by means of a dynamo generator having a considerably increased efficiency.

According to the invention, a bicycle lighting system of the present development is characterized in that the dynamo system is arranged and constructed such, that - from a minimum travel speed of about 5 to 7 kmph - it generates an electric power adequate to charge the battery and at the same time feed the front-light and the rear-light, and that the converter arrangement has an up-converting and down-converting function and is additionally fed from the battery as long as the minimum travel speed is not reached.

In a preferred embodiment the converter arrangement comprises an energy-converter and energy-limiter device and a threshold-value device detecting a rectified dynamo output voltage, whereby in case the threshold-value device detects that a specified minimum voltage of the dynamo generator is exceeded, the voltage supplied from the battery is fed - in addition to the rectified output voltage of the dynamo generator - by means of an electronic switchgear to the energy-converter and energy-limiter device, and whereby the output voltages of the energy-converter and energy-limiter device is within a first constant output voltage range U_{a1} during battery operation and within a second constant output voltage range U_{a2} during dynamo operation, the latter range being above the first constant output voltage range, and a battery charging device is activated above an output charging voltage which is between the first constant output voltage range and the second constant output voltage range (refer to Figures 5a, 5b and 5c).

The first constant output voltage range U_{a1} of the converter arrangement is preferably within a fixedly set range from



4.5 V to 6 V. During this mode of operation, the input voltage range of the converter lies between 0.8 V minimum threshold-value voltage and a maximum switch-over voltage of 4.8 V. The second constant output voltage range U_{a2} of the converter arrangement is preferably within a range between 6.2 V and 7 V, but advantageously above 6.4 V. During this mode of operation, the input voltage range of the converter lies in an initial speed range between approximately 5 V and then goes up to maximum 80 V (at about 80 kmph) (refer to Figures 5a and 5c). By virtue of this setting of the converter arrangement in accordance with the invention, the legal rule or standard is ideally met at each and every traveling speed. The combination of a high-efficiency dynamo generator with the converter arrangement and the accumulator battery renders possible a combined battery-charging, standing-light and traveling-light system. The converter arrangement is operated by the battery as well as directly by the dynamo generator.

The energy-converter and energy-limiter device preferably limits the output of the converter arrangement invariably to 4 W up to 6 W, advantageously to 4.5 W up to 5 W. In this manner, the short-circuit safety of the battery and of the dynamo generator as well as of the dynamo system is also ensured.

In a further preferred construction, the converter arrangement further comprises: a rectifier circuit for producing a rectified and smoothed dynamo output voltage which is fed to the energy-converter and energy-limiter device, a first voltage divider network which converts a first rectified and speed-proportional output voltage of the dynamo generator into a first component voltage and supplies this component voltage to a first threshold-value switch, a second voltage divider



network which converts the rectified and speed-proportional output voltage of the dynamo generator into a second component voltage and supplies the latter to a second threshold-value switch, whereby the first threshold-value switch applies the battery voltage to the energy-converter and energy-limiter device by means of the electronic switchgear when the rectified output voltage of the dynamo generator has exceeded a first threshold voltage detected by the first threshold-value switch, and the second threshold-value switch sends a signal to the energy-converter and energy-limiter device for switching over the output voltage of the latter from the first constant output voltage to the second constant output voltage, and vice versa, whenever the second threshold-value switch detects that a second threshold voltage is not reached or is exceeded, respectively, a delay circuit connected with the output of the first threshold-value switch and with the electronic switchgear and which, in case the rectified output voltage of the dynamo generator falls short of the first threshold voltage, opens the electronic switchgear at the end of a predetermined period of time (e.g. four minutes) in order to switch off the voltage of the battery from the input of the energy-converter and energy-limiter device, and a battery charging converter which is coupled at the output side with the energy-converter and energy-limiter device and which, in the case of battery operation, also remains activated for charging the battery.

The first threshold-value switch switches on the battery voltage at a threshold voltage V_x of approximately 0.8 V by means of the electronic switchgear.

The battery charging converter operates at an output voltage U_a of 6.1 V up to maximum 7 V proportionally increasing with higher power conversion depending on the charging condition of the battery.

In order to ensure the required characteristic features of the dynamo system, there are provided a dynamo generator comprising a high efficiency and a very low internal resistance and which, already at a speed of approximately 5 to 7 kmph, generates an output of at least 4.5 W at a low output voltage, and a converter arrangement which converts this output of the dynamo generator into an output voltage of 6.2 V to 7 V. In order to achieve the high efficiency, the dynamo generator moreover comprises an inner circuit and an outer circuit (refer to Figures 1a and 1b), both of which are mounted for synchronous rotation in the same direction about a stationary air-core coil, whereby the inner circuit and the outer circuit comprise in each case n poles in identical pole pitch.

Owing to the fact that an inner circuit and an outer circuit can synchronously rotate in the same sense of rotation about a stationary air-core coil, there is achieved - in conjunction with progressive powerful magnets as well as an extremely low internal resistance of the coil, which is preferably lower than 1.5 ohms - a high field strength for a relatively small iron-and-magnet volume and with low hysteresis losses. The actually effective magnetic circuit consists of two partial circuits MK1 and MK2 (refer to Figure 1a).

The inner circuit preferably comprises n (preferably six by way of example) inner pole shoes, and at each inner pole shoe there are two magnetic poles laterally arranged in homopolar configuration. In this manner, the two magnetic surfaces project themselves upon the pole-shoe surface (b_1 in Figure 1a). Since the two magnetic surfaces are preferably far larger than the pole-shoe surface, the density of the magnetic flux correspondingly increases onto the pole-shoe surface.

Furthermore, this arrangement is advantageous in that the pole shoes (e to d, Figure 1b) of the inner circuit possess a relatively small mass and thereby render possible a weight reduction. The magnetic flux is apportioned over the outer circuit in two parts directed onto the oppositely situated outer pole shoes (g to m in Figure 1b).

The outer circuit likewise comprises n (preferably six) outer pole shoes which are oppositely arranged relative to the inner pole shoes and nose-shapedly projecting toward the latter, these outer pole shoes being structured such that each air gap between the inner pole shoes and the respective outer pole shoes assigned to the latter is the shortest path for the magnetic flux (MK1; MK2). In this manner, the magnetic leakage flux is advantageously reduced.

In order to reduce the mutual interference of the homopolar magnets, each inner pole shoe is divided in the middle into two identical parts by a slot producing an air gap in radial direction. This arrangement results in the additional advantage of a smaller pole-shoe volume as well as larger magnet heights, this meaning that two half magnet-lengths per pole together with at the same time the smallest magnet-volume and the double magnet-surface are possible.

The air gap in the inner pole shoes reduces the mutual interference of the two homopolar magnet faces, because the magnetic flux glides in each case with respective halves over the pole shoe to the outer circuit. The two magnetic fluxes in each pole shoe possess an optimally short magnetic-circuit path, so that the result is an optimal magnetic flux. A further advantage is seen in the fact that a very small generator with extremely high flux densities can be produced, such generator having at

the same time a light-weight, small magnet-volume and high-efficiency structure. The efficiency achievable by means of the proposed dynamo generator of the bicycle lighting system according to the invention is at least approximately 90%.

By way of example, the thereby resulting actual efficiency of the entire bicycle lighting system according to the invention for 3 W luminous power and 1 W battery charging energy is - with reference to 3 W - approximately 60% in the case of a discharged accumulator battery and 80% in the case of a charged accumulator battery.

Furthermore, it is advantageous that the air-core coil comprises a very low inductance (lower than 150 μ H, preferably lower than 100 μ H). In this manner, there is produced a negligible counter inductance, whereby the pole sensitivity is hardly or not at all noticeable while, at the same time, the induction losses are extremely low.

Preferably, the coil (23) is divided per pole field into two identical coil sections which are pole-correctly connected in series (23.1 to 23.6 in Figure 2a).

Although the invention particularly refers to a bicycle lighting system, it is evident for one skilled in the art that the characteristics of the dynamo generator according to the invention can also be employed for other generator applications.

The inventive characteristics of the magnet arrangement and of the magnetic-circuit structure can be advantageously utilized for electric motors.

Further features and advantages will be described hereinafter on the basis of a bicycle lighting system with a dynamo generator as the preferred exemplary embodiment such as is illustrated in the drawings, wherein:

Figures 1a and 1b show a cross-section through a preferred exemplary embodiment of a dynamo generator as is utilized in the invention;

Figures 2a and 2b respectively show the inner magnetic-circuit arrangement and the arrangement of the stationary coil in a perspective cross-sectional illustration and a stretched illustration of the coil arrangement;

Figure 3 schematically shows a block diagram of a preferred exemplary embodiment of the bicycle lighting system according to the invention, whereby - in particular - the proposed converter arrangement (5) becomes apparent;

Figures 4a to 4e respectively show voltage/speed-time diagrams and a voltage-time diagram for the purpose of explaining the function of the invention;

Figures 5a, 5b and 5c show voltage-speed diagrams to further explain the function of the invention, whereby Figure 5a applies to a discharged or defective battery and Figure 5c applies to a normal battery;

Figure 6 shows an accomplished embodiment of the circuit arrangement of the bicycle lighting system according to the invention and realized by means of a customized integrated solid-state switching circuit (ASIC);

Figure 7 shows a longitudinal sectional view through a first exemplary embodiment of the dynamo system structured as a side-dynamo system; and

Figure 8 shows a longitudinal sectional view through a second exemplary embodiment of the dynamo system structured as a roller-dynamo system.

The preferred exemplary embodiment of the dynamo generator utilized according to the invention and illustrated in Figures 1a and 1b comprises in concentric arrangement from the inside to the outside a rotating inner circuit 21, a stationary air-core coil 23 (23.1 to 23.6) and an outer circuit 22 synchronously rotating with the inner circuit 21. In the exemplary embodiment depicted in Figure 1b, the inner circuit 21 and the outer circuit 22 each comprise six poles (a-f) situated opposite each other in identical pole pitch, so that the resulting pole-pitch angle is 60° . The six poles of the inner circuit 21 are structured in the form of six pole shoes a-f, while the poles of the outer circuit are structured in the form of likewise six pole shoes g-m, which are situated opposite to the pole shoes a-f of the inner circuit and nose-shapedly project toward the latter, so that a smallest possible air gap 30 is formed. The pole shoes a-f of the inner circuit are made of soft iron, while the support (41) of the inner magnetic circuit is itself non-ferrous. The outer circuit consists entirely of soft iron. (The number of poles, namely six, is specified only by way of a preferred example.)

Between the pole shoes a-f of the inner circuit 21 there are arranged six permanent magnets 24-29 in such a manner, that in each case they rest homopolar against both sides of each pole shoe. The result is that the two magnet surfaces, which

at the magnets 24 and 29 are designated by reference characters a_1 and a_2 (magnet width), project themselves upon the pole-shoe surface b_1 (pole shoe f). The magnet lengths M_1 (Figure 2a) of the permanent magnets 24-29 extending perpendicularly with respect to the paper-surface plane of Figure 1 and the entire arrangement are determined such, that in each case the sum of the respective magnet surfaces a_1+a_2 is far larger than the respective pole-shoe surface b_1 . In this manner, the magnetic flux density correspondingly increases onto the pole-shoe surface b_1 . This arrangement is furthermore advantageous in that the six pole shoes a-f of the inner circuit possess a relatively small mass, so that a weight reduction is rendered possible.

However, the entire rotating part of the dynamo generator possesses, mainly because of the rotating outer circuit, a relatively high moment of inertia, so that the wheel slippage behavior is substantially improved.

The magnetic flux is divided across the respective nose-shapedly projecting pole shoes g-m of the outer circuit 22 into two parts (MK1 and MK2; refer to Figure 1b). By virtue of the nose-shaped form of the pole shoes g-m of the outer circuit, such form being also adapted to the periphery of the coil, there results the air gap 30, as indicated between a pole-shoe pair, namely f and m, as the shortest path for the magnetic flux. The magnetic leakage flux is thus reduced.

In order to reduce interaction of the homopolar magnets resting against both sides of the respective pole shoes a-f of the inner circuit 21, these pole shoes a-f are slit in the middle by respective radial air gaps 31-36. The advantage of this arrangement is seen in a small pole-shoe volume with large

magnet heights, i.e. two magnet widths per pole with, at the same time, the smallest magnet volume and double magnet surface.

The radial gaps 31-36 in the pole shoes a-f prevent interaction of the two homopolar magnet-face surfaces, since the magnetic flux flows each in halves over the pole shoe at the outer circuits. The two magnetic flux halves in a pole shoe have an optimally short magnetic circuit path (MK1 and MK2). The result is an optimal magnetic flux. A further advantage is that, in this manner, a small dynamo generator with extremely high flux density, low weight, small magnet volume, homogeneous magnetic loading and a very high efficiency can be realized.

The Figure 2a illustrates the inner magnetic circuit as well as the coil arrangement of the preferred dynamo generator in a perspective cross-sectional view. In Figure 2b, there is shown in a stretched arrangement a segment of the wire-wound coil in the sequence 23_2 , 23_1 , 23_6 and 23_5 , which together with the pole shoes b, a, f, e form the pole fields N_3 , S_2 and N_1 . The coil connections and the two winding directions designated I and II of the coil sections 23_2 , 23_1 , 23_6 and 23_5 are schematically indicated.

Since one coil is guided normally over two heteropolar poles, three coils are required for a six-polar arrangement which is not particularly illustrated. In this manner, the air-core coil 23 depicted in Figures 1a) and 1b) and in Figures 2a) and 2b) is divided per pole field into two identical coil sections 23.1 to 23.6 (refer to Figures 2a and 2b), which are pole-correctly connected in series. There is thus achieved a smaller overall height, i.e. that in the case of six poles

there are provided six coil sections arranged at an angular pitch of 60° .

In order to fabricate the stationary air-core coil the windings consisting of self-bonding enamelled copper wire are wound in self-contained manner and bent onto the reference circle of the coil arrangement. The coils are inserted in a suitable plastic injection molding die. The mutual coil connections are already connected and mounted at a connection pin plug (39 in Figure 7). The plastic injection molding die includes at the same time the housing base part (37 in Figure 7). Subsequently, the whole unit is injection molded with plastic material to form a leadless plug-in component. This type of construction renders possible that the electronic part can be plugged in directly at the housing base of the dynamo system. A further wiring is thus unnecessary. The wires of the stationary air-core coil have been previously processed and require no subsequent treatment or refinishing.

The process described hereinbefore renders possible an air-core coil 23 comprising a very low inductance, i.e. preferably lower than $150 \mu\text{H}$. In this manner, there is produced a negligible counter inductance, whereby the pole sensitivity is hardly or not at all noticeable. The coil resistance is preferably lower than 1.6 ohms, whereby - in the case of an actually accomplished construction of the dynamo generator - the resulting magnetic loading is larger than 0.6 T. (In the realized construction of the dynamo generator the average coil diameter was 31 mm, the magnet length 30 mm and the outer diameter approximately 44 mm. A reduced coil length 40 (Figure 2b and Figure 7) of about 20 mm is strived for, with which it would possible to also improve the essential inventive power characteristics of the dynamo generator.

The construction and the mode of operation of the entire dynamo system and particularly of a preferred exemplary embodiment of the converter arrangement will be hereinafter explained by referring to Figures 3, 4 and 5.

Figure 3 illustrates a block diagram of a preferred exemplary embodiment of the bicycle lighting system constructed in accordance with the invention. The electric alternating voltage produced by the dynamo generator 1 structured in the foregoing described manner is rectified by a rectifier 11 and smoothed by a capacitor C_1 . At a circuit node 18 there is formed the sum of the rectified dynamo voltage U_{eDYN} and the battery voltage U_{BATT} as will be hereinafter described. The combined voltage U_{eDYN} and U_{BATT} produced at the circuit node 18 is applied at the input side of an energy-converter and energy-limiter device 10 which converts this voltage/power to 6 V and 6.4 V, respectively. This energy-converter and energy-limiter device 10 possesses the characteristic feature of optimally adapting itself to the internal resistance of the dynamo generator 1. In the case of a low input voltage (low traveling speed), the energy-converter and energy-limiter device 10 raises the resulting voltage (power). In the case of a higher traveling speed and thus of a high output voltage and output power of the dynamo generator, the energy-converter and energy-limiter device 10 lowers the voltage available at the circuit node 18 to preferably 6.4 V at the output side U_a and keeps this voltage substantially constant with a variation range of approximately ± 10 mV. By virtue of the application of electronic components representing the latest state of the art, such as Schottky diodes and power FETs (field effect transistors), there can be achieved an efficiency of the energy-converter and energy-limiter device 10 of better than 85%. The efficiency is approximately 85% in the case of low

voltages, and when there are high input voltages at the circuit node 18 (e.g. about 9 V), the efficiency of the energy-converter and energy-limiter device 10 is above 90%.

The overall performance of the converter arrangement 5 will be better understood when consideration is now given to the function of a first threshold-value switch 13, a second threshold-value switch 15 as well as a delay circuit 17 and a battery monitoring circuit 19.

First threshold-value switch 13

The output voltage of the dynamo generator 1 is rectified by means of a rectifier consisting of two diodes D_3 and D_4 and smoothed by a capacitor C_4 . This voltage V_x is proportional to the ridden speed. It is divided by means of a first voltage divider 12, which consists of two resistors R_1 and R_2 , and supplied to the input of the first threshold-value switch 13 (voltage U_{T1}). This first threshold-value switch activates a gate circuit T_1 at an input voltage higher than $V_x = 0.8$ V. This means that, by means of the gate circuit T_1 , the voltage of the battery 4 is supplied to the summing circuit node 18 by means of an electronic switch S_1 16 and a protective diode D_1 . A further output of the first threshold-value switch 13 sets the delay circuit 17 to zero (static).

If the input voltage of the first threshold-value switch 13 is lower than $V_x = 0.8$ V, the delay circuit 17 is started. The latter comprises an oscillator and counting chains. The battery voltage remains available at the summing circuit node 18 by means of the gate circuit T_1 , the electronic switchgear 16 and the protective diode D_1 , until the output of the delay

circuit 17 opens the electronic switchgear 16 by means of the gate circuit T_1 . The battery voltage is then cut off. The gate circuit T_1 is thus activated with the first threshold-value switch 13 and moves up with the start of the delay circuit 17. In case the battery 4 is completely discharged or defective or non-existent, the activation at the circuit node 18 will be prevented by means of the battery monitoring circuit 19.

Second threshold-value switch 15

The speed-proportional voltage of the dynamo generator 1 resulting at the capacitor C_4 is supplied via a second voltage divider 14, which consists of two resistors R_3 and R_4 , to the second threshold-value switch 15 (voltage U_{T2}). The latter activates by means of an output signal the energy-converter and energy-limiter device 10 in the case of a dynamo-generator output voltage lower than $V_x = 4.5$ V, whereby an output voltage of the energy-converter and energy-limiter device 10 of adjustable 4.5 V to 6 V (U_{a1}) is reached. If the output voltage of the dynamo generator 1 is above 4.8 V, the energy-converter and energy-limiter device 10 is set by means of the output signal of the second threshold-value switch 15 in such a manner, that it produces 6.4 V (U_{a2}) at the output thereof. This implies that, by virtue of the mode of operation of the preferred exemplary embodiment of the converter arrangement 5 depicted in Figure 3, with an input voltage U_{T2} of the second threshold-value switch 15 when V_x of the latter is lower than 4.5 V, voltage is procured from the battery for the purpose of producing standing light, and that with an input voltage U_{T2} of the second threshold-value switch 15 when V_x is higher than 4.8 V, output voltage (traveling voltage) is procured from the dynamo

generator 1. The change-over from battery operation to dynamo operation occurs smoothly.

At the output of the energy-converter and energy-limiter device 10 there is connected a charging converter 20 which feeds the battery 4 as soon as the output voltage U_a exceeds 6.1 V and rises up to 6.4 V by proportionally increasing in dependence on the charge condition of the accumulator battery 4. It is thereby ensured that no battery charging occurs during battery standing-light operation. It is furthermore ensured that the voltage does not fall below 6 V when the energy of the dynamo generator is insufficient.

The resistance voltage divider R_5 , R_6 connected to the output of the energy-converter and energy-limiter device 10 delivers a control signal U_{T3} for the control of the output voltage U_a (feedback). This control voltage is influenced by the second threshold-value switch 15.

The functions of the converter arrangement 5 schematically illustrated in Figure 3 will be discussed more fully hereinafter, particularly in conjunction with Figures 4a to 4e and Figures 5a to 5c. The Figures 4a to 4e schematically show in graphical representation the chronological dependence of the voltages U_g ($U_g \approx V_x$), U_{T1} and U_{T2} (a component voltage of V_x), which are respectively produced by the first voltage divider 12 and the second voltage divider 14 and which are supplied to the first threshold-value switch 13 and to the second threshold-value switch 15, respectively, whereby the approximately linear and speed-proportional dependence of these voltages is assumed such, that they rise from zero starting at a moment of time $t_1(t_1')$ up to a moment of time $t_3(t_3')$ (in accordance with an assumed increase in speed from

zero to 30 kmph) and then again drop approximately linearly from $t_3(t_3')$ to a moment of time $t_5(t_5')$. At the moment of time $t_1(t_1')$, at which the voltage U_{T1} reaches $V_x = 0.8$ V, the first threshold-value switch 13 is activated, and at the moment of time $t_5(t_5')$ at which this voltage again falls short of $V_x = 0.8$ V, the first threshold-value switch 13 is deactivated (start and travel operation). Between the moments of time $t_1(t_1')$ and $t_5(t_5')$ the delay circuit 17 remains inactive. At the moment of time $t_5(t_5')$ the delay circuit 17 starts measuring the delay of, for instance, four minutes, which is terminated at a moment of time t_8 (Figure 4c), and opens the electronic switchgear 16 by means of the gate circuit T_1 and thereby cuts off the battery voltage. If the dynamo voltage rises prior to the end of the delay time (e.g. 4 minutes) t_5-t_1' (Figure 4a), the delay circuit is made inactive by the first threshold-value switch 13 and the functions recommence as at the moment of time $t_1(t_1')$.

The second threshold-value switch 15 (Figure 3) is activated at a moment of time t_2 by means of the second voltage divider 14 (Figure 3), i.e. by the voltage U_{T2} when the voltage V_x exceeds 4.8 V (Figure 4d). When the voltage V_x falls short of 4.5 V at the moment of time t_4 (Figure 4d), the second threshold-value switch 15 is deactivated by means of the second voltage divider 14, i.e. by the voltage U_{T2} . During the activation period of the second threshold-value switch the energy-converter and energy-limiter device 10 (Figure 3) converts the output voltage U_{a2} to preferred 6.4 V. This occurs as soon as the traveling speed exceeds approximately 5 to 7 kmph (Figures 4a and 4e). In the inactive range of the second threshold-value switch (traveling speed lower than 3 kmph), the energy-converter and energy-limiter device 10 converts the output voltage U_{a1} to 4.5 V up to 6 V, preferably

fixedly set, for instance, to 5.5 V as illustrated in Figure 4e.

The function-time diagrams depicted in Figures 4a to 4e are combined in the voltage-speed diagram illustrated in Figures 5a to 5c. The change-over from $U_a = 4.5$ V to $U_a = 6.4$ V occurs at a traveling speed of about 5 to 7 kmph.

The function-time diagrams depicted in Figures 4a to 4e illustrate - dependent on the voltage-speed/variation-in-time diagram (Figure 4a) - the respective functions of the first threshold-value switch 13 (Figure 4b), of the delay circuit 17 (Figure 4c), of the second threshold-value switch 15 (Figure 4d) and of the output voltage U_a (U_{a1} , U_{a2}) (Figure 4e).

The delay circuit 17 is activated when the threshold voltage V_x falls short of approximately 0.8 V (in other words, the bicycle comes to a stop). The delay circuit 17 now supplies by means of the gate T_1 and the switch S_1 (Figure 3) during a period of four minutes the voltage of the battery 4 to the circuit node 18 and thus to the energy-converter and energy-limiter device 10. The latter now produces the output voltage (standing light). At the end of the time interval of four minutes, the switch S_1 is opened and the entire system is thereby switched off. In case the first threshold-value switch 13 exceeds the control signal V_x , when during the delay interval the voltage V_x is equal to 0.8 V, the delay circuit 17 is set back to zero and there commences the normal traveling program as described hereinbefore under "First threshold-value switch 13"

Summarized, this means that when the bicycle comes to a stop, the standing light burns at least four minutes long and, upon starting anew, the lighting system changes over without interruption to the traveling program.

The battery-charge monitoring circuit 19 (Figure 3) monitors the battery with respect to the charge condition and the operational capability thereof. In case the battery is discharged or not capable of functioning, the battery-charge monitoring circuit 19 will prevent the connection of the batteries to the circuit node 18, so that the system is thereby run and operated according to Figure 5a directly by means of the dynamo generator U_g (in such case without standing light) and the energy-converter and energy-limiter device 10. It is thereby ensured that the batteries are protected against total discharge.

Figures 5a, 5b and 5c illustrate the course of the output voltage U_a achieved by the bicycle lighting system according to the invention, such course being depicted in the form of a curve K_1 extending between the hatched legally standardized range. The course of the output voltage is designated by U_{a1} and U_{a2} (Figure 5b). On the other hand, a curve K_2 (Figure 5a) shows the course of the output voltage of a conventional bicycle lighting system. The standing-light range is designated by reference character STL and extends over a speed range from zero to about 5 kmph.

The aforescribed bicycle lighting system and the dynamo system thus have particularly the following advantages:

- 4 The dynamo generator disposes of a very high efficiency which produces a power output of more than 4.5 W at a

traveling speed of approximately 5 to 7 kmph;

- this dynamo power is converted to 6.4 V and kept constant at a speed above approximately 5 kmph by means of the up-converting and down-converting converter arrangement;
- this energy is now directly available, on the one hand, for charging the battery and, on the other hand, for generating light;
- the converter arrangement operates already from 2 V with an input voltage starting from 1.5 V and up to 80 V (80 V corresponding with approximately 80 kmph);
- the ratio of energy apportioning in traveling light and standing light is obtained in a ratio of 1-2:1, this meaning two units traveling light and one unit standing light, irrespective of the speed. This apportioning ratio is currently still limited by the charging capacity of accumulator batteries. The ratio can be substantially reversed in the case of an augmented charging capacity and could be, for instance, a ratio of 0.5:1. However, such batteries are currently still not available or have other drawbacks;
- the bicycle lighting system meets by far the legal dynamo-travel-power curve, because constant and adequate energy for light and battery charging is non-intermittently available;
- with the effected apportionment of the output voltage of the energy-converter and energy-limiter device 10 of the converter arrangement 5 to provide an output voltage of

4.5 up to 6 V below a speed of approximately 5 kmph and a "travel" voltage of 6.4 V, the Standard exacting 3 W for standstill and for any traveling speed is ideally fulfilled;

- the battery-charging balance is reliably ensured;
- by virtue of the superior efficiency of the entire bicycle lighting system there is achieved a far lower riding resistance. In other words, the pedaling energy to move and actuate the dynamo system is substantially reduced in spite of increased dynamo power;
- the application of the air-core coil in the dynamo generator eliminates magnetic ripple formation;
- the dynamo generator has very low inductive losses, requires no sliding contacts and is, therefore, better and more reliable; and
- finally, the rotary motion of the entire magnetic circuit (outer circuit and inner circuit) eliminates the magnetic losses of the dynamo generator.

Figure 6 shows an exemplary preferred realization of the converter arrangement 5 by means of a customized, integrated, solid-state switching circuit 50, at pins of which there are connected external switching elements of the converter circuit.

Since all electronic functions are complex and costly and since the construction, which includes integrated standard switching circuits, would require a large number of components

as well as a great deal of space, there are sensibly realized all functions (digital and analog functions) in a One-Chip-ASIC 50. A bicycle lighting system being a mass-produced or bulk article, it is evident that mass production of the customized, integrated, solid-state switching circuit 50 is also economically worth-while. Components that cannot be integrated or cannot be sensibly integrated, such as the rectifier 11, a transformer T, the capacitors C₁, C₂, C₃, C₄, a power output transistor and further component parts, are connected to the pins of the customized, integrated, solid-state switching circuit 50 in the circuit arrangement illustrated in Figure 6.

By providing a customized, solid-state, integrated switching circuit 50 for the electronic functions of the converter arrangement 5, the latter can be realized very compact and small, so that it can be accommodated together with the battery 4 in a small housing which is either integrated with the dynamo housing or separately mountable thereat.

Figure 7 depicts a longitudinal section through an exemplary embodiment of the dynamo generator 1 suggested according to the invention as a side dynamo including an integrated battery 4 and an integrated converter arrangement 5. The dynamo system 1 is mounted in known manner at a swivel arm 34 and comprises an upper housing portion 30 which encompasses the rotating inner circuit and outer circuit and the stationary coils 23.1-23.6, and a lower housing portion 31 which encompasses the battery 4 and the converter arrangement 5, this lower housing portion 31 being fixedly connected with the upper housing portion 30. The coil sections 23.1-23.6 are integrally formed with a housing base 37. The converter arrangement 5 is connected by means of guide pins 39 with the coil sections

23.1-23.6. Connections 33 to the lamps are located in the lower part of the lower housing portion 31. At the dynamo system there is provided a sensor S₂ which detects that the dynamo system is not ready-for-operation in the idle position and supplies a signal to the converter arrangement 5 (Figure 3), thus effecting immediate interruption of the existing standing light. This sensor (S₂ in Figure 3), serving to deenergize the entire bicycle lighting system when the dynamo system is tilted away, is accommodated in the housing of the swivel arm 34. A driving wheel 35 driven by the bicycle wheel is fixedly connected with a dynamo arbor 38 which, in turn, is connected with the support core of the inner circuit. This dynamo arbor 38 is freely rotatably mounted in an upper pivot bearing 36 and a lower pivot bearing 36'. Although the dynamo system depicted in a longitudinal sectional view in Figure 7 is constructed as a side dynamo system, it will be readily clear to one skilled in the art that the aforescribed particular characteristics of the dynamo system 1 constructed according to the invention are also applicable for a roller dynamo system (Figure 8) or for a hub dynamo system.

Of course, there can be provided an alternative embodiment of the dynamo system in that the converter arrangement 5 shown in Figure 6, the external components thereof and the battery can also be kept apart from the dynamo generator and arranged separately on the bicycle.



PATENT CLAIMS

1. Bicycle lighting system comprising a dynamo system (1, 5) which includes a dynamo generator (1) and is drivable by a ridden bicycle and mounted thereat,

at least one front-light (2) and

at least one rear-light (3), both of which are supplied with electric power from the dynamo system (1, 5), and

a converter arrangement (5) which converts the electric power generated by the dynamo generator (1) into a regulated direct-current voltage for generating light and for charging an accumulator battery (4),

characterized in that

the dynamo system (1) is arranged and constructed such, that from a minimum traveling speed of approximately 5 to 7 kmph it generates an electric power adequate to charge the battery (4) and simultaneously feed the front-light (2) and the rear-light (3), and

the converter arrangement (5) has an up-converting and down-converting function and is additionally fed from the battery (4) as long as the minimum traveling speed is not reached.

2. Bicycle lighting system according to claim 1, characterized in that the converter arrangement (5) comprises an



energy-converter and energy-limiter device (10) and a threshold-value device (12-17) which detects a rectified dynamo output voltage (U_{eDYN}), whereby in case the threshold-value device detects that a specified minimum voltage of the dynamo generator is exceeded, the voltage (U_{BATT}) supplied from the battery (4) is fed, in addition to the rectified output voltage (U_{eDYN}) of the dynamo generator (1), by means of an electronic switchgear (16) to the energy-converter and energy-limiter device (10), and

that the output voltage (U_a) of the energy-converter and energy-limiter device (10) is during battery operation within a first constant output voltage range (U_{a1}) and during dynamo operation within a second constant output voltage range (U_{a2}), the latter being above the first constant output voltage range (U_{a1}), and that a battery charging device (20) is activated above an output charging voltage (U_0) which is between the first constant output voltage range (U_{a1}) and the second constant output voltage range (U_{a2}).

3. Bicycle lighting system according to claim 2, characterized in that the first constant output voltage range (U_{a1}) of the converter arrangement lies in a range from 4 to 6 V, preferably from 4.5 to 6 V, and the output charging voltage (U_0) is preferably 6.1 V.
4. Bicycle lighting system according to claim 2 or claim 3, characterized in that the energy-converter and energy-limiter device (10) limits the output of the converter arrangement (5) invariably to 4 up to 6 W, preferably to 4.5 up to 5 W.



5. Bicycle lighting system according to one of the claims 1 through 4, characterized in that the converter arrangement (5) further comprises:

- a rectifier circuit (11) for producing a rectified and smoothed dynamo output voltage (U_{eDYN}) which is supplied to the energy-converter and energy-limiter device (10);
- a first voltage divider network (12, R_1 , R_2) which converts a first rectified output voltage of the dynamo, which voltage is proportional to the traveling speed, into a first component voltage (U_{T1}) and supplies this component voltage to a first threshold-value switch (13);
- a second voltage divider network (14, R_3 , R_4) which converts the rectified output voltage (U_{eDYN}) of the dynamo generator (1), which voltage is proportional to the traveling speed, into a second component voltage (U_{T2}) and supplies the latter to a second threshold-value switch (15), whereby

the first threshold-value switch (13) applies the battery voltage (U_{BATT}) to the energy-converter and energy-limiter device (10) by means of the electronic switchgear (16) when the rectified voltage (U_{eDYN}) supplied from the dynamo generator (1) has exceeded a first threshold voltage detected by the first threshold-value switch, and the second threshold-value switch supplies to the energy-converter and energy-limiter device (10) a signal to switch over the output voltage thereof from the first constant output voltage (U_{a1}) to the second constant output voltage (U_{a2}) and vice versa whenever the second threshold-value switch (15) detects that a second threshold voltage is not reached or is exceeded, respectively;



- a delay circuit (17) which is connected with the output of the first threshold-value switch (13) and with the electronic switchgear (16), and which, in case the rectified output voltage (U_{eDYN}) from the dynamo generator (1) falls short of the first threshold voltage, opens the electronic switchgear (16) at the end of a predetermined period of time, in order to switch off the voltage (U_{BATT}) of the battery (4) from the input of the energy-converter and energy-limiter device (10), and

- a battery charging converter (20) which is coupled at the output side with the energy-converter and energy-limiter device (10) and which also during battery operation remains activated for charging the battery (4).

6. Bicycle lighting system according to one of the claims 1 through 5, characterized in that there is provided at the dynamo system (1, 5) a sensor (S_2 , 32) which detects that the dynamo system in the inoperative position is not ready for operation and which supplies a signal to the converter arrangement (5), such signal immediately cutting off the existing standing light.
7. Bicycle lighting system according to one or more of the previous claims, characterized in that the dynamo generator (1) comprises an inner circuit (21) and an outer circuit (22), both of which are mounted for synchronous rotation in the same direction about a stationary air-core coil consisting of coil sections (23.1-23.6), and

that the inner circuit (21) and the outer circuit (22) each comprise n poles (a-f, g-m) in identical pole pitch.



8. Dynamo generator (1) according to claim 7, characterized in that the inner circuit (21) comprises n inner pole shoes (a-f), and

that at each of these inner pole shoes (a-f) there are laterally arranged two magnetic poles (M_1-M_2 , M_3-M_4 , M_5-M_6 , M_7-M_8 , M_9-M_{10} , $M_{11}-M_{12}$) in homopolar configuration.
9. Dynamo generator (1) according to claim 7 or claim 8, characterized in that the outer circuit (22) comprises n outer pole shoes (g-m) which lie opposite to the inner pole shoes (a-f) and which nose-shapedly project to the latter, the outer pole shoes being structured such, that each air gap between the inner pole shoes and the respective outer pole shoes is the shortest path for the magnetic flux.
10. Dynamo generator (1) according to one of the claims 7, 8 and 9, characterized in that each inner pole shoe (a-f) comprises in the mid-portion thereof a slot (31-36) extending in radial direction and forming an air gap, in order to reduce mutual interference of the respective two magnets (M_1 , M_2 ...) laterally lying against the respective inner pole shoe (a-f)
11. Dynamo generator (1) according to one or more of the claims 7 through 10, characterized in that the sum (a_1+a_2) of the two lateral adjacent surfaces (a_1 , a_2) of the two lateral magnets adjacent to the respective inner pole shoe (a-f) is larger than the peripheral surface (b_1) of each inner pole shoe (a-f).
12. Dynamo generator (1) according to one or more of the claims 7 through 11, characterized in that the inductance



of the air-core coil (23) of the dynamo generator (1) is smaller than 150 μ H.

13. Dynamo generator (1) according to claim 12, characterized in that the coil resistance of the air-core coil (23) and the internal resistance of the dynamo generator (1) are smaller than 1.5 ohms.
14. Dynamo generator (1) according to one or more of the claims 7 through 13, characterized in that the air-core coil (23) is divided per pole field into two identical coil sections (23.1-23.6) which are pole-correctly connected in series.
15. Dynamo generator (1) according to one or more of the claims 7 through 14, characterized in that the number of poles n is at least four, but preferably six.
16. Dynamo system (1, 5) with a dynamo generator (1) according to one or more of the claims 7 through 15, characterized in that the power output at a traveling speed of 3.5 up to 5 kmph and with a load resistance of 3 ohms is at least 3 W, and at a traveling speed of 7 kmph is more than 4.5 W.
17. Dynamo system (1, 5) with a dynamo generator (1) according to one or more of the claims 7 through 16, characterized in that the produced output voltage of the dynamo generator varies by approximately 0.8 to 1.2 V per 1 kmph variation in speed of the driving vehicle.



18. Dynamo system (1, 5) with a dynamo generator (1) according to one or more of the claims 7 through 17, characterized in that the dynamo generator (1) is realized as a side dynamo (Figure 7) or as a roller dynamo (Figure 8).
19. Dynamo system (1, 5) with a dynamo generator (1) according to one or more of the claims 7 through 18, characterized in that the converter arrangement (5) (Figure 3) comprises a customized, solid-state, integrated switching circuit (ASIC 50) (Figure 6).
20. Dynamo system (1, 5) with a dynamo generator (1) according to one or more of the claims 7 through 19, characterized in that the converter arrangement (5) is arranged together with the battery (4) in a housing apart from the dynamo generator (1).
21. Dynamo system (1, 5) with a dynamo generator (1) according to one of the claims 18 to 20, characterized in that the separate housing (31) of the converter arrangement is mounted at the housing (30, 37) of the dynamo generator (1).
22. Dynamo system (1, 5) with a dynamo generator (1) according to one of the claims 7 to 19, characterized in that the converter arrangement (5) and the battery (4) are arranged together with the dynamo generator (1) in a two-part housing.
23. Structure of the dynamo generator (1) according to claims 7 through 15, characterized by the use of the



characteristics of the magnet arrangement and of the magnetic circuit structure for generators in general.

24. Structure of the dynamo generator (1) according to claims 7 through 15, characterized by the use of the characteristics of the magnet arrangement and of the magnetic circuit structure for electric motors.

