Query on the Sustainable Development of Traditional Dust Precipitation Using Optimal Electric Spark Rate

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Abstract: Based on analysis on the physical nature of dust precipitation using optimal electric spark rate and some problems relating to dust removing effects, high consumption of electric power and steel material, this article brings forward the query on its sustainable development. Finally this article points out that dust precipitation using direct current supply with extra wide polar distance is the solution to these problems.

Keywords: dust precipitation optimal electric spark rate, negative resistance, sustainable development, dust precipitation using direct current supply with extra wide polar distance

1 FOREWORD

During the ICESP—X academic conference[1] we pointed out that dust precipitation using direct current supply with extra wide polar distance can save 50%-90% power energy compared with the traditional dust precipitation using optimal electric spark rate. Our purpose is to promote the use of dust precipitation using direct current supply with extra wide polar distance in the field of dust removal and to provide theoretical basis and practical references for our proposal.

Based on analysis on the physical nature of worldwide use of dust precipitation using optimal electric spark rate and prevalent sustainable development strategy of "Environment Protection, Energy Preservation and Resources Preservation" this article brings forward the essential query on the theory of dust precipitation using optimal electric spark rate. The co-authors of this article pointed out that during the past half century unsatisfactory static dust removing, excessive waste of energy and steel material were more or less related with the misleading concept of "optimal electric spark rate".

This article will further provide theoretical basis for use of dust precipitation using direct current supply with extra wide polar distance in the field of dust removal.

2 PHYSICAL NATURE OF DUST PRECIPITATION USING OPTIMAL ELECTRIC SPARK RATE

2.1 Optimization of Electric Spark Rate" is the Synonym for "Optimization of Electric Pressure in Electric Field

A dust removing system using optimal electric spark rate can be shown in a simplified equivalent circuit chart shown in the following Fig. 1. In the figurer stands for equivalent average internal resistance of power currency, internal resistance for short; R stands for the equivalent average resistance, load resistance for short; I_0 stands for average load resistance; U_i stands for average power supply pressure; U_0 stands for load voltage of dust precipitator.

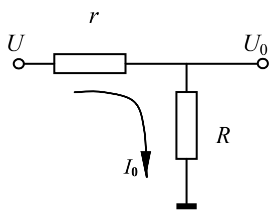


Fig. 1 Equivalent Principle Chart for Dust Precipitation System Using Optimal Electric Spark Rate

Then we get:

$$U_0 = U_i - rI_0 \tag{1}$$

Differentiate I_0

$$\frac{dU_0}{dI_0} = \frac{dU_i}{dI_0} - r \tag{2}$$

When negative resistance component produced during electric spark discharging is gradually increased in R the $\frac{dU_0}{dI_0} = 0$ motion resistance will happen,

$$\frac{dU_0}{dI_0} = \frac{dU_i}{dI_0} - r = 0$$

Then work out the condition for emergence of maximum point B of U_0

$$\frac{dU_i}{dI_0} = r \tag{3}$$

See Fig. 2 where stands for U_i-I_0 curve; b is U_0-I_0; c stands for dust removing efficiency η-$I0$; d stands for electric spark rate f- I_0.

Obviously the extreme maximum value U_{0m} appears when condition (3) is satisfied.

From our literature [1] we know that the average power rate Pf used for dust catching in electric field is:

$$P_f = \frac{Q^2 \cdot E^2 \cdot t^2}{2m} \tag{4}$$

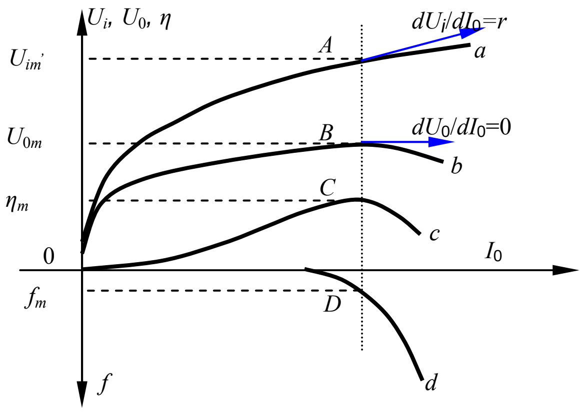


Fig. 2 Sketch Map for Dust Precipitation System Using Optimal Electric Spark Rate Behavior

Where the electric field intensity E is directly proportional to electric field voltage U_0. From this we get the following conclusion: when the above described electric spark rate reaches to a certain value fm the extreme maximum value U_{0m} will appear followed by the dust removing efficiency extreme maximum value η_m; So, electric spark rate corresponding to U_{0m} is generally referred to as "optimal electric spark rate".

Equation (3) can be regarded as the condition for existence of "optimal electric spark rate" because the extreme maximum value U0m appears under this condition.

We can see that the so called "optimization of electric spark rate" is just a synonym for "maximization of electric field voltage". This is one of the physical natures of dust precipitation using optimal electric spark rate.

2.2 Optimal Electric Spark Rate is not Directly Corresponding to Maximum Value of Dust Precipitation Efficiency

If we study carefully the condition (3) for the existence of optimal electric spark rate fm we find a strange phenomenon: r on the right end of condition (3) is completely unrelated to fm. It is not related to η_m either; On the left end of condition (3) any negative resistance factor relating to dU_i introduced to dI0 can lead to appearance of the above described U0m. However, these introduced negative resistances could be completely unrelated to dust precipitation efficiency. This means that complete elimination of dust removing efficiency curve c from Fig. 2 will not affect the "optimal electric spark rate".

This shows that the so called maximum dust removing efficiency is just a related result of jointly induced by r and electric sparking negative effect. There is no corresponding relationship between electric spark rate and dust removing efficiency. On the contrary, "non-dust precipitation" during electric sparking and the defective time slot for power supply are negatively affect dust removing efficiency.

Accordingly we can conclude that optimal electric spark rate is not directly corresponding to maximum value of dust precipitation efficiency. Therefore, optimal electric spark rate should not be targeted as goal value for maximum dust precipitation efficiency. This is the second nature of dust removing using optimal electric spark rate.

2.3 Optimal Electric Spark Rate is the Synonym for Maximization of Power Consumption at Electric Field

Power consumption equation P_0 can be got from Fig. 1:

$$P_0 = U_i \cdot I_0 - rI_0^2 \tag{5}$$

Derivation of I_0 ,

$$\frac{dP_0}{dI_0} = \frac{dU_i}{dI_0} \cdot I_0 + U_i - 2r \cdot I_0$$

Suppose the maximum point P_{0m} on P_0 , there must be. $\frac{dP_0}{dI_0} = 0$, then：

$$\frac{dU_i}{dI_0} \cdot I_0 + U_i - 2rI_0 = 0 \tag{6}$$

In fact $I_0 \neq 0$ at P_{0m} , so the above equation can be divided with I_0

$$\frac{dU_i}{dI_0} + \frac{U_i}{I_0} = 2r$$

We get $U_i I_0 = rI_0^2 + C_2$

Because there is no energy storing organism in the system and $I_0 \neq 0$ at maximum point, therefore：

$$\frac{dU_i}{dI_0} = r \tag{7}$$

We can see that condition (7) is the same as condition (3). In other words, when maximum value U_{0m} appears the maximum power consumption value P_{0m} also appears.

From this we conclude that the above described optimization of electric spark rate is also a synonym for maximization of power consumption at electric field. This is the third physical nature of dust precipitation using optimal electric spark rate.

3 THE CONCEPT OF OPTIMAL ELECTRIC SPARK RATE IS MISLEADING

When this concept first came out in 1950 it caused a revolution in the field of static dust precipitation. Since then dust precipitation with optimal electric spark of power supply has been playing a dominating role. However, the co-authors of this article pointed out that engineering practice in the past half century proved that the concept of optimal electric spark rate is quite misleading.

Misunderstanding is often related to the following four aspects.

3.1 Dust Removing Efficiency η_m under "Optimal Electric Spark Rate" Condition is not the Maximum Value η_{max}

As we mentioned before, in a certain dust removing system when electric spark rate f reaches to a certain value, VA character of the electric field will be induced to give a maximum value driven by internal resistance r and spark rate *f*. Accordingly this power supply and electric field will match to produce the maximum power supply pressure and maximum dust removing efficiency value η_m. This is the so called "optimal electric spark rate". However, it is wrong to conclude that this dust removing system has achieved the "maximum dust removing efficiency" η_{max} and is better than other dust removing systems. This wrong conclusion is caused by the misunderstanding of "optimal electric spark rate" concept.

See Fig. 3. Suppose U_{0B}=65 kV and $\beta = 2\pi/3$ under η_m; Suppose B' is the critical point for electric sparking in electric field and the corresponding average voltage $U_{0B'}$=60 kV, then the instantaneous maximum value U_P=125.7 kV. This means that normal dust removing is possible in electric field where instantaneous voltage of direct current U_0 is less than 125 kV. Then the electric field voltage U_0=U_p which is 92% higher than U_B . We thus get the following conclusion : the corresponding dust removing efficiency η_B of the latter is far higher than the dust removing efficiency η_B of the optimal electric spark rate.

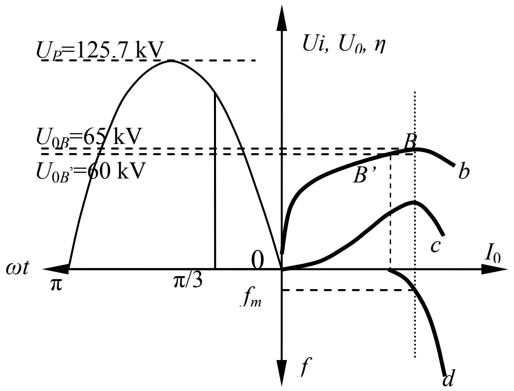


Fig. 3 Dust Removing Status Comparison between Power Current and Direct Current $U_0 \leq U_P$(=125 kV)

In fact, the scientific research results of those experts from Xiamen Luyang provides us very good basis for our discussion. See Fig. 4. Their research result proves that in the same electric field when optimal electric spark rate is controlled at U_{0m}=68 kV, dust removing efficiency η_m=66.4%; If we use three-phase full wave rectifier circuit the dust removing efficiency η=95.5%>>η_m even when U_0=78 kV. No need for electric sparking, let alone optimal spark rate.

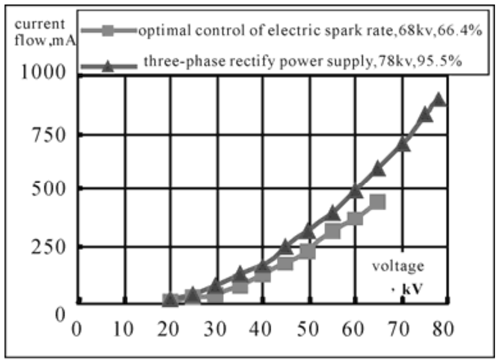


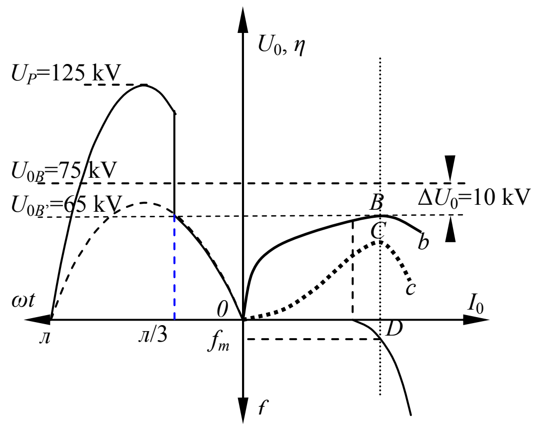
Fig. 4 An Example showing η_{max} higher than η_m

We find that dust removing efficiency η_m under optimal electric spark rate is just an extreme value phenomenon under a certain condition in the system. It is not the biggest dust removing value η_{max} achievable in this system. So the practicality of this method is doubtful.

3.2 "Optimization of Electric Spark Rate" is More Often a Power Control Process in Engineering Practice

Conclusion from section 2.3 tells us that electric spark rate should not be targeted as the goal quantity for optimal dust removing efficiency. Therefore , in engineering practice the control of optimal electric spark rate is haphazard and random. The following examples show that control of optimal electric spark rate is a diversified strategy.

On the whole, these diversified "optimal electric spark rate" control strategies will produce total different power control characters: when the average output voltage is the same there will be quite different instantaneous voltage maximum value; when instantaneous voltages are the same there will be different voltage average values. So the "optimization of electric spark rate" in engineering practice is a process of power supply control instead of a nature formation of "optimal electric spark rate" described in the above section 2. Therefore in a certain dust precipitator electric field power supply of different controlled character will produce different "optimal electric spark rate" fm , which will then bring us different "optimal dust removing efficiency"



ηm. For instance, experts from National Power Environmental Protection combined AM-PM to improve the control character of power current as is shown in Fig. 5. Under maximum identical voltage value and identical angle of flow when the average value of voltage output from power supply of common phase modulation is 65 kV the average value of voltage output from power supply of amplitude modulation is 75 kV. This means that under the same "optimal electric spark rate fm" the latter will improve dust-removing efficiency enormously.

Fig. 6 AM-PM conversion and phase modulation of power supply.

3.3 Narrow Pole Span is the Result of Misleading Concept of Optimal Electric Spark Rate

The direct control goal for dust precipitation is the spark discharge at electric field and to get the "optimal electric spark rate" fm. If wide pole span is used in electric field the power supply should provide much higher voltage than the present narrow pole span. Then the instantaneous value will be more than one hundred thousand volts, which has a high requirement for safety, reliability and insulation as well as maintainability of the high pressure power system. In fact, present narrow pole span matching condition and waste of steel materials are caused by limitation of power supply voltage grade and pole span.

3.4 Necessity to Use Power Current is the Result of Misleading Concept of Optimal Electric Spark Rate

Theoretically the pursuit of optimal electric spark rate fm excludes the use direct current for dust removing and power current has become the excusive power supply. Theory and practice shows that dust precipitation can be accomplished without electric spark discharge. So power current is not the only power supply for static dust precipitation.

4 QUERY ON THE SUSTAINABILITY FOR DEVELOPMENT OF TRADITIONAL DUST PRECIPITATION USING OPTIMAL ELECTRIC SPARK RATE

The above analysis on the physical natures of dust precipitation using optimal electric spark rate as well as on misleading concept of optimal electric spark rate are in fact queries on its practicability. In this section we will give further analysis from the perspective of sustainable development.

4.1 On Dust Removing Effectiveness

As we pointed out in the above Section 2.2 that optimal electric spark rate does not correspond to the maximum value of dust removing effectiveness. In Section 3.1 we pointed out that dust removing efficiency η_m under "optimal electric spark rate" is not the maximum value $\eta_{\max.}$ Section 3.2 tells us that optimization of electric spark rate is often a power character control process in engineering practice. Different dust removing efficiencies can be achieved under the same "optimal electric spark rate fm" condition. Experts from State Power Environmental Protection Research Institute combined AM-PM to improve the control character of power current in stead of phase modulation. Under the same "optimal electric spark rate fm" they improve dust-removing efficiency enormously.

All these shows that the practical effectiveness of prevalent dust removing method is doubtful because it is dust removing result is not the best. Moreover, it often occurs that power current supply fails to increase in electric field, thus causing limit of dust removing improvement. This can hinder the sustainable development of dust precipitation.

4.2 On Waste of Energy

It is well known that theoretically dust precipitation with optimal electric spark rate must use power current supply. However, our thesis Discovery of Power Energy Conservation By Adoption of Direct Current Supply[1] presented on ICESP—X conference pointed out that dust removing with power current supply consumes much more energy than direct current. Current-limiting reactor will reduce 30% of the average power to dust precipitator electric field. And the electric field using power current consumes 50%-90% more power than using direct current.

Therefore we have well-founded reasons to bring forward queries on the sustainability of development of traditional dust precipitation using optimal electric spark rate. Aside from its unideal dust removing effect this method also wastes large amount of energy.

4.3 On Waste of Resources

As we pointed out before that restrained by reliability and cost-effectiveness dust precipitators using optimal electric spark rate in engineering practice are all using electric field with narrow pole span structure. Their homopolar span is usually 200 mm-300 mm. So 400m is regarded as wide pole span. Compared with the dust precipitation electric field of direct current supply, which can easily achieve 500 mm-700 mm homopolar span, the former will waste at least 10% of steel. These wasted steel materials are of good quality.

Clearly we have well-founded reasons to bring forward queries on the sustainability of development of traditional dust precipitation using optimal electric spark rate, for it wastes great amount of steels.

5 DUST PRECIPITATION USING DIRECT CURRENT SUPPLY WITH EXTRA WIDE POLAR DISTANCE IS THE SOLUTION

Our purpose of the above analysis and queries on dust precipitation with optimal electric spark rate is to seek a solution for its future sustainable development. But where is the solution?

Based on the principle brought forward in our literature[1] we think that dust precipitation using direct current supply with extra wide polar distance is the solution to all the mentioned shortcomings.

5.1 Modern Direct Current Supply

(1) Dust precipitation using direct current supply does not require electric spark discharge in electric field. It does not need the optimal electric spark rate as the controlled target quantity. Therefore, it can easily achieve electric field condition without spark discharge. Extra wide polar distance electric field also avoids limit caused by unideal spark discharge by direct current.

(2) With the fast development of technology many high voltage DC supplies are capable of prevention and resisting against accidental electric spark discharge and high pressure short circuit problems. For instance, the F-series DC static dust precipitation power supply manufactured by Automation Research Institute of Shijiazhuang City is capable of long time operation with short circuit, long time open running and incidental high voltage striking fire. Tested on 2*80M2, 165M2 sintering plants of Shougang Group (listed company) and 2*75M2 of Shuangliang Group Power Plant (listed company) DC static dust precipitation power supplies are good choices for dust precipitation using direct current supply of wide pole span.

(3) DC power supply with extra wide pole span can save enormous power energy and power capacity volume is reduced, thus enabling minimization, integration of control and high voltage (e.g. F-series power supplies). They help to provide conveniences for operation, use and maintenance.

5.2 Improved Dust Removing Effect

(1) In a dust precipitation system using DC power supply of wide pole span the system can continue to work with increased power pressure U_i on condition that no electric spark is not discharged. This provides a wider adjustable room for dust removing effect.

(2) It is quite easy for DC power supply to use attached high frequency waviness or high frequency pulse as an auxiliary means to improve dust removing effect, for instance, the F-series high frequency inversion power supply. It is of great significance to solve problems under high ratio resistance.

(3) In a dust precipitation system using DC power supply of wide pole span the electric field intensity E is much less than that in a system using optimal electric spark rate. Phenomena like burr wire balls and back corona are weakened, thus guaranteeing long-term dust removing effect.

(4) To replace power current supply with DC supply can improve dust-removing effect in a certain degree. But this cannot meet requirement for “energy conservation” described in next section.

5.3 Energy Conservation

(1) Electric reactor is not required in the dust removing system using DC supply, thus enabling 30% more average electric power in the electric field. Power is saved.

(2) Without power consumption for spark discharge and additional consumption of “bell current flow” from power current the electric field intensity E required for extra wide pole span is not as high as that for optimal spark rate field. Accordingly power consumption will be reduced more 50%. The experiences got in the sinter plant in Shougang Group and Shuangliang Power Plant proved that dust-removing system using DC power supply can save about 90% power energy.

5.4 Conservation of Steel Material

To widen pole span will save a large amount of anode plate and cathode wire. Load reduction on suspension system and the supporting structure will also save large amount of steels.

Experiences show that about 10%–20% steel materials can be saved.

6 CONCLUSIONS

From the perspective of sustainable development the co-authors of this article analyzed the physical natures of dust removing using optimal electric spark rate and pointed out that both theoretically and practically electric spark rate does not correspond to dust removing efficiency directly. It is wrong to target “electric spark rate” as the goal control quantity in order to get the best dust removing effect. Dust removing effect achieved from the so called “dust precipitation using optimal electric spark rate” is not the maximum efficiency in a certain electric field. In fact, most traditional dust precipitation system using optimal electric spark rate is not “best spark rate system” in its true sense. Moreover, these systems consume more steel materials and power energy. This is quite against the principle of sustainable development strategy. Theory and engineering practice show that dust precipitation using DC extra wide pole span can eliminate shortcomings brought by dust precipitation using optimal electric spark rate. It proves to be a feasible technical solution.

We believe that, from the perspective of sustainable development strategy, the discovery of physical nature of dust precipitation using optimal electric spark rate, proposition of dust precipitation using DC supply of extra wide pole span as well as power conservation proposal are of great significance for the progress of static dust removing technology.

REFERENCES

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