Light Metals 2011 *Edited by: Stephen J. Lindsay*
TMS (The Minerals, Metals & Materials Society), 2011

TECHNOLOGY & EQUIPMENT FOR STARTING UP & SHUTTING DOWN ALUMINIUM POTS UNDER FULL AMPERAGE

Yang Tao, Cao Bin, Li Meng, Yi Xiaobing

(Guiyang Aluminum Magnesium Design and Research institute , Guiyang 550083, China)

Key words: status breakup; voltage grade; idle power consumption; aluminum production decrease; emission decrease of equivalent weight carbon dioxide

Abstract

This paper presents the basic principle, technical solution and key equipment of the technology of pot startup/stoppage under full amperage, based on the design and production properties of aluminum smelting potline. In addition, it provides for a benefits analysis brought by this technology on energy saving, production increase and emission decrease. Also presented is the current application status of this technology.

Theoretical Basis

The modern large aluminum electrolysis potline is basically composed of a few hundreds of pots connected in series, this kind of series potline is powered by high amperage DC power source, potline voltage is above 1000V, but pot voltage is normally around 4.2V. In order to carry out overhaul for certain single pot without interrupting other pots' normal production, parallel bypass—short circuit busbar at pot bottom is designed for each pot, each busbar at pot bottom is connected to the short-circuit piece via flexibles, shown as the following circuit schematic diagram, See fiure 1.

When pot is under normal production status, a electric insulation plate is inserted between short-circuit piece and busbar riser, and no current goes through, but current only goes through pot for electrochemical reaction; However, when pot is stopped, the short-circuit piece and busbar riser are pressed together via bolt for current going through, then the potline current goes via the busbar at pot bottom to the downstream pot. The gap between the short-circuit piece and busbar riser is called short-circuit mouth.

If the short-circuit mouth is directly opened and/or closed under high amperage of DC, a DC arc with high energy will be produced, which may cause personal harm and damage to equipment. It's different from AC that a DC arc has high energy and is difficult to be extinguished.

Therefore, it's a must to close and open the short-circuit mouth, in order to startup and/or stop a pot under full potline current. However, it is the key problem for theoretic study that how to reduce the DC arcing energy between the short-circuit piece and busbar riser during short circuit mouth operation.

Based on electric contact theory [1], the following basic concepts can be obtained:

The less the electric potential and its variation gradient of the short circuit mouth contact surface before and after opening and closing is, the less the total arcing energy is.

The less the current and its variation gradient of the short circuit mouth contact surface before and after opening and closing is, the less the total arcing energy is.

The shorter the opening or closing duration of the short circuit mouth contact surface is, the less the total arcing energy is.

Based on the theoretic analysis conclusion, the following technical targets can be determined:

To reduce the electric potential of the short circuit contact surface before and after opening and closing[2].

To reduce the current variation gradient of the short circuit contact surface before and after opening and closing.

To open and close the short circuit mouth rapidly, non-manually, and with remote control.

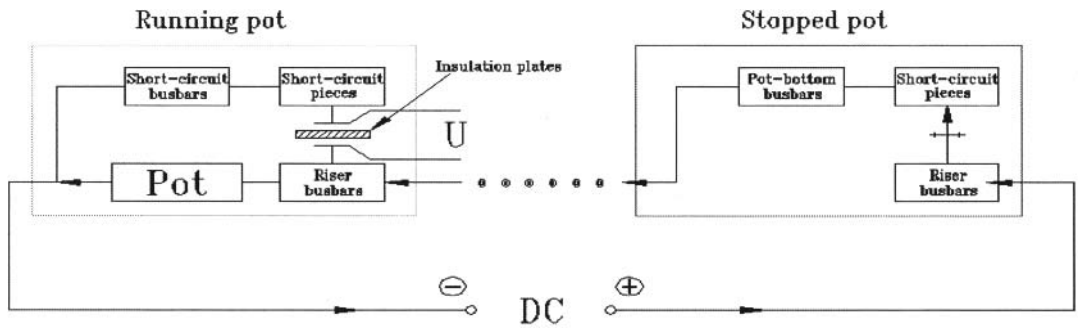


Figure 1 Circuit Schematic Diagram of Running Pot and Stopped Pot

Technical Solution

The following technical solution can be determined as figure 3, based on the above mentioned technical targets:

To fit one parallel bypass between the busbar riser and short circuit piece, to reduce the electric potential and current variation gradient of the short circuit mouth contact surface before and after opening and closing, so as to reduce the DC arc energy produced when opening and closing the short circuit mouth.

To design mechanical device to quickly and simultaneously open/close the short circuit mouth, to realize the quick opening and closing of short circuit mouth, reduce the duration, and reduce the total DC arcing energy; to realize the opening and closing of short circuit mouth non-manually, with remote control, to increase security; in addition, to realize the gang control with current diversion switch.

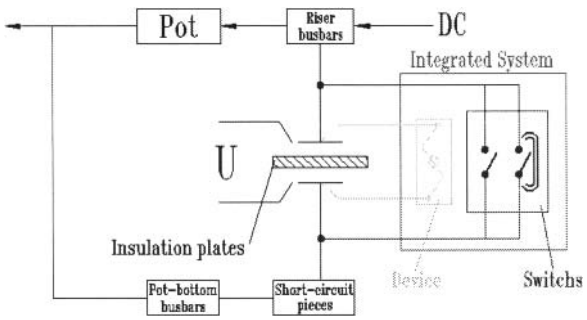


Figure 2 Schematic Diagram of Technical Solution

To design a control cabinet to manipulate the action of switch group and device group remotely.

This kind of device is directly installed at the short circuit mouth when starting and stopping a pot. For stopping a pot, first, close the current diversion switch to reduce the electric potential at the short circuit mouth, and then quickly close the short circuit piece by mechanical driving to short out the pot from potline; For starting a pot, first, close the current diversion switch to reduce the electric potential at the short circuit mouth, then open the short circuit piece by mechanical driving, and finally shut off the current diversion switch to connect the pot to potline.

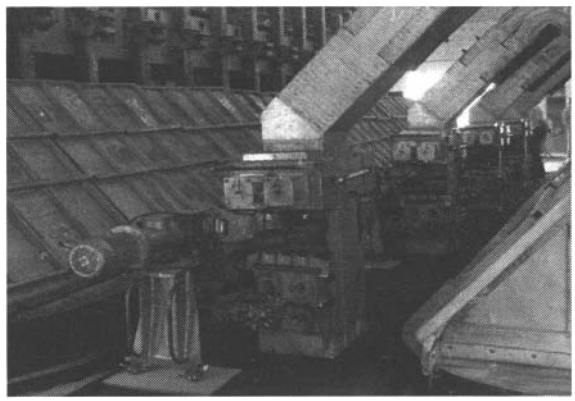


Figure 3 Picture of Equipment Site Installation

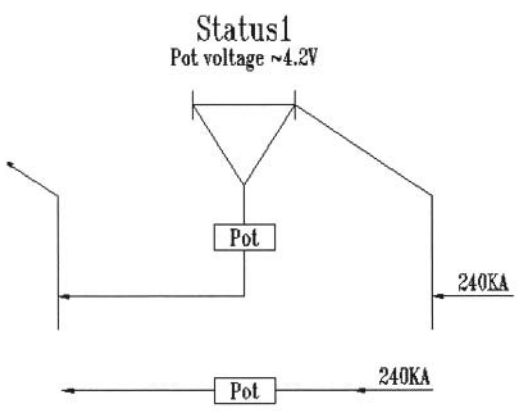
Procedure Analysis

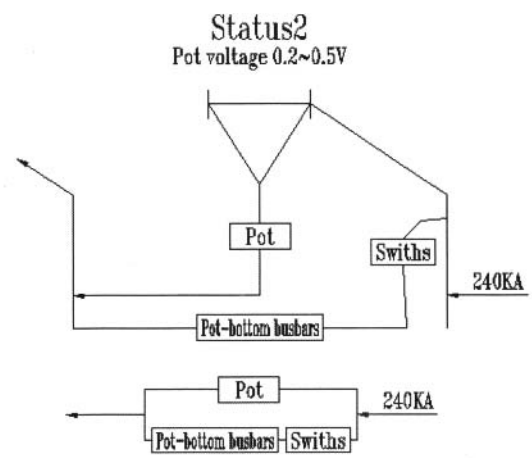
Procedure of Pot Stoppage

Pot stoppage is to short out the on-line running pots for overhaul, and the short circuit mouth is closed, instead of opened.

Procedure Breakup

The short circuit mouth of on-line running pot is under switch is closed, close and tightly press the short circuit piece with the mechanical open/close device, and then fix it by screwing down the bolt; finally, disconnect the current diversion switch, and the pot stoppage procedure is finished. The procedure of pot stoppage is divided into 6 current through-flow statuses, and these statuses along various paths are shown as follows:





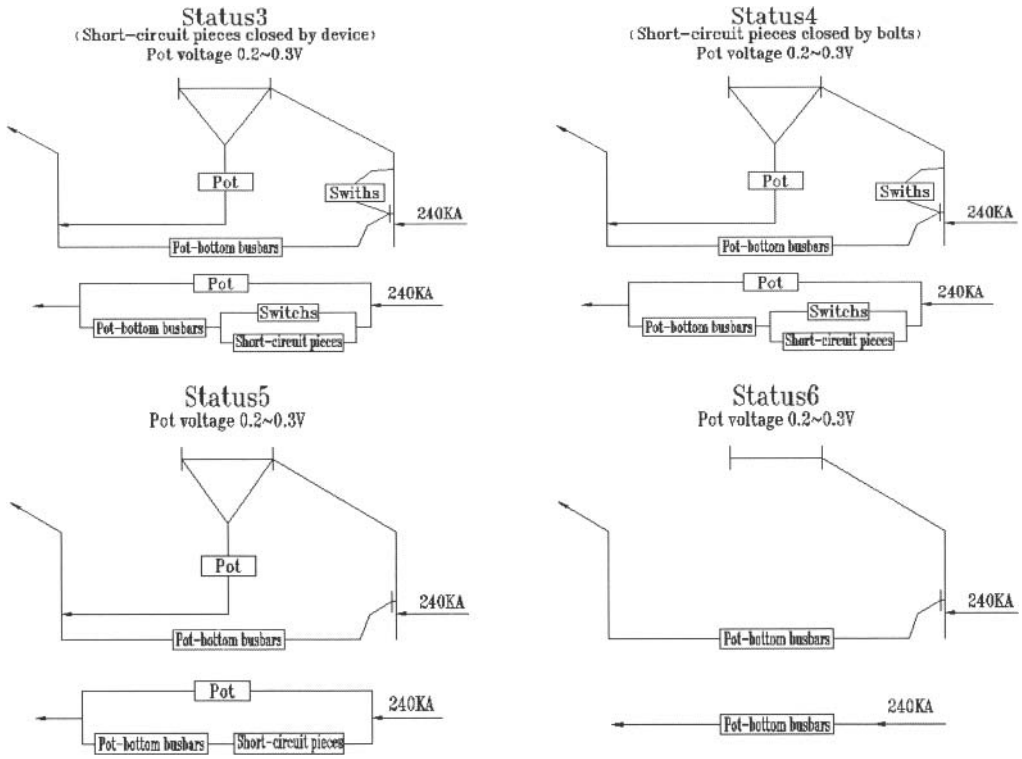


Figure 4 Current Through-flow Status during Pot Stoppage

Status Analysis

Take one 240 kA pot for example, the current distribution along various paths under various statuses during pot stoppage are shown in following table 1.

Table 1 Current Distribution List during Pot Stoppage (unit: A)

Status	Pot	Busbar at Pot Bottom		Voltage (mV)	Operation	Duration
		Switch Group	Short Circuit Piece Group			
Status 1	240000	0	0	4200	Normal running	
Status 1_1	64889	175111	0	1136	Close switch 1	Less than 5ms
Status 1_2	37781	202219	0	661	Close switch 2	
Status 1_3	26649	213351	0	466	Close switch 3	
Status 2	20504	219496	0	359	Close switch 4	
Status 2_1	17651	188956	33393	309	Close short circuit piece 1	Less than 500ms
Status 2_2	17027	182276	40696	298	Close short circuit piece 2	
Status 2_3	15880	169999	54121	278	Close short circuit piece 3	
Status 2_4	14463	154824	70713	253	Close short circuit piece 4	
Status 2_5	13729	146965	79306	240	Close short circuit piece 5	
Status 2_6	12687	135813	91500	222	Close short circuit piece 6	
Status 2_7	11613	124315	104072	203	Close short circuit piece 7	
Status 3	11276	120706	108018	197	Close short circuit piece 8	
Status 4	9963	106650	123387	174	Screw down the bolt at short circuit mouth	Around 10min
Status 4_1	11220	89826	138954	196	Disconnect switch 1	Less than 5ms
Status 4_2	12809	68557	158634	224	Disconnect switch 2	
Status 4_3	14922	40269	184808	261	Disconnect switch 3	
Status 5	17931	0	222069	314	Disconnect switch 4	
Status 6	0	0	240000	339	Take anodes out	

The short circuit mouth is pressed in two closed statuses by two ways, one is by mechanical open/close device and another is by bolt, the former is just the transition status during work process, and the latter is the target status of pot short circuit, the pressing force of the former is less than that of the latter, so, there is more current passing the short circuit mouth when the bolt is screwed down. Short-circuit pieces in status 3 are closed by mechanical open/close device, and in status 4 they are closed status by bolts.

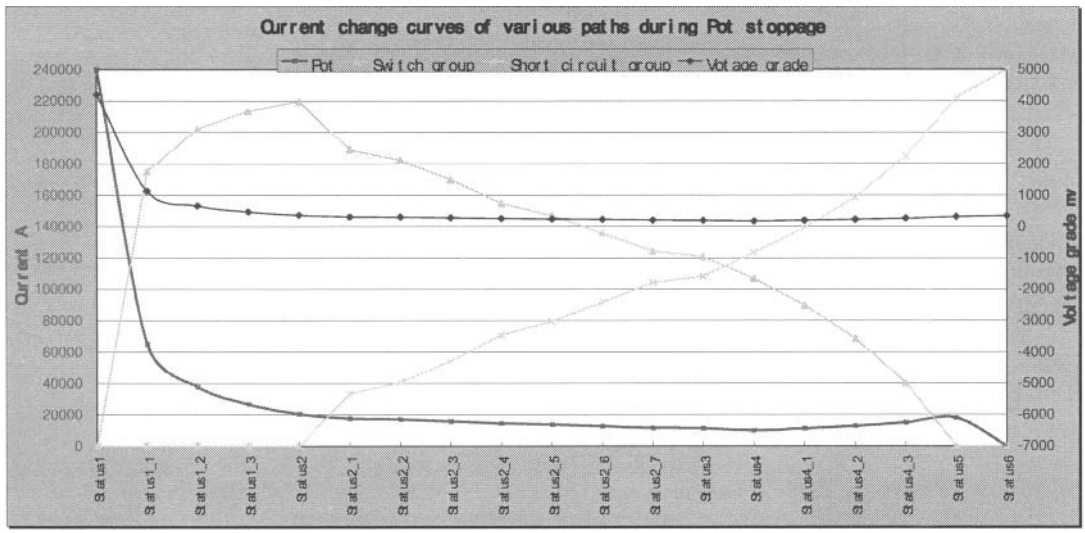


Figure 5 Current Change Curve of All Paths during Pot Stoppage

It's indicated by table 1 and figure 5: normal pot voltage 4200mv (status 1), pot current 100%; when current diversion switch group is all connected (status 2), voltage reduces to 359mv, i.e. reduces 12 times, and 91.5% current is bypassed by switch group; subsequently, when short circuit piece group is closed in turn (status 3), the current bypassed by short circuit piece group increases from 0% to 45.0%, and the current bypassed by switch group reduces to 50.3%; when switch group is disconnected in turn, the current bypassed by switch group reduces gradually to 0%, however, the current bypassed by short circuit piece group again increases gradually to 92.5%; when anodes are taken out, the current at short circuit group increases to 100%, and current diversion from pot to short circuit mouth group is finished.

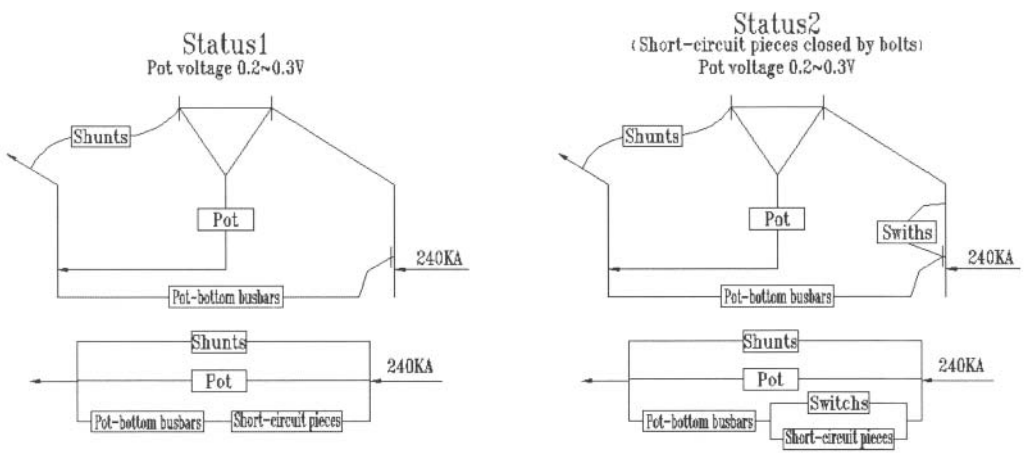
From status 2 to status 5, i.e. switch group status changes from closed to disconnected, voltage only changes within lower and small range of 197~309mv, therefore, the arcing energy at short circuit mouth is effectively controlled, and the operation security at short circuit mouth is also ensured.

Procedure of Pot Startup

Pot startup is to power on the overhauled pot and connect to the potline, and the short circuit mouth is disconnected, instead of closed.

Procedure Breakup

The short circuit mouth of the pot which is to be powered on for baking is under closed status, current flows via the short circuited busbar at pot bottom to downstream pots, and pot voltage is within 0.2v~0.3V; during pot startup, first install shunts between the side B big busbar of the target pot and the side A busbar riser of the downstream pot; close the current diversion switch; press the short circuit mouth tightly with the mechanical open/close device; loosen the bolt; close the current diversion switch; open the short circuit mouth with the mechanical open/close device, and insert insulation plate; finally, disconnect the current diversion switch, and pot startup procedure is finished. Similarly, the procedure of pot startup is divided into 6 current through-flow statuses, and they are shown as follows:



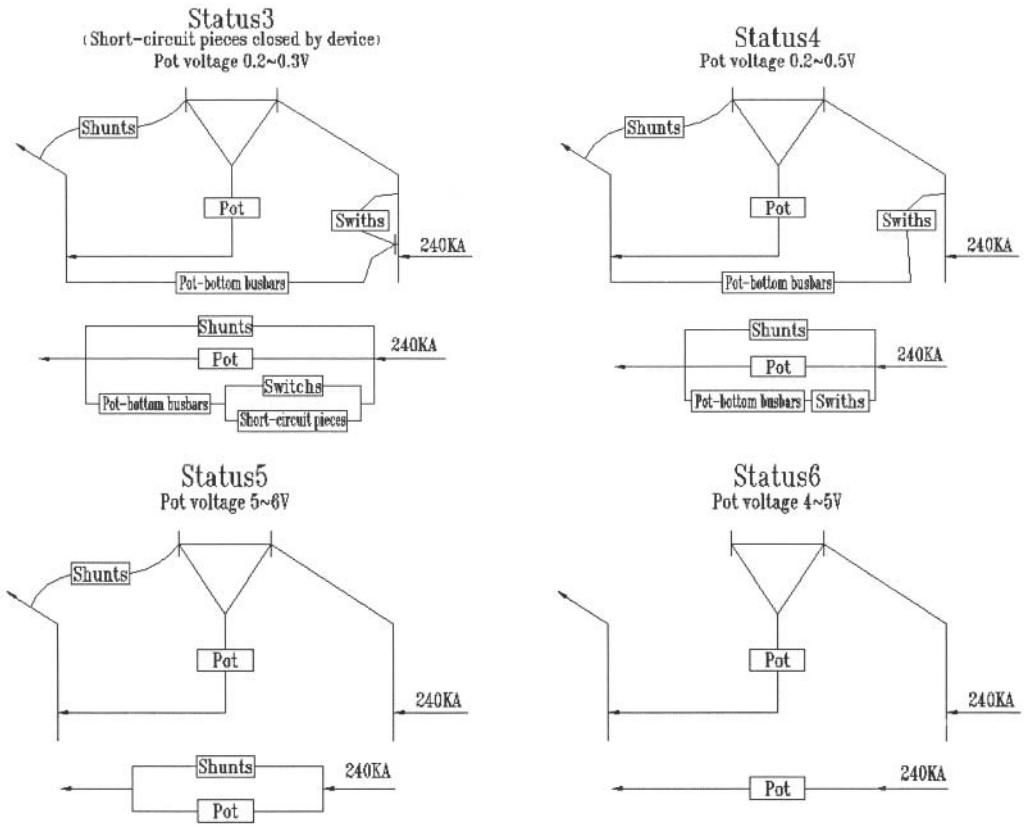


Figure 6 Current Through-flow Status during Pot Startup

Status Analysis

The current distribution percentages along various paths under various statuses during pot startup are shown in following table:

Table 2 Current Distribution List during Pot Startup (unit: A)

Status	Pot	Busbar at Pot Bottom		Shunts	Voltage (mV)	Operation	Duration
		Switch Group	Short Circuit Piece Group				
Status 1	6420	0	227161	6420	321	Install shunts	
Status 1_1	5322	41037	188319	5322	266	Close switch 1	Less than 5ms
Status 1_2	4556	69674	161214	4556	228	Close switch 2	
Status 1_3	3983	91105	140929	3983	199	Close switch 3	
Status 2	3531	107995	124943	3531	177	Close switch 4	
Status 3	4003	122431	109563	4003	200	Loosen the bolt at short circuit mouth	Around 15min
Status 3_1	4116	125894	105874	4116	206	Open short circuit piece 1	Less than 500ms
Status 3_2	4517	138168	92797	4517	226	Open short circuit piece 2	
Status 3_3	4714	144177	86395	4714	236	Open short circuit piece 3	
Status 3_4	5219	159622	69940	5219	261	Open short circuit piece 4	
Status 3_5	5451	166714	62384	5451	273	Open short circuit piece 5	
Status 3_6	6099	186544	41258	6099	305	Open short circuit piece 6	
Status 3_7	6317	193194	34173	6317	316	Open short circuit piece 7	
Status 4	7365	225269	0	7365	368	Open short circuit piece 8	
Status 4_1	9648	220703	0	9648	482	Disconnect switch 1	Less than 5ms
Status 4_2	13879	212242	0	13879	694	Disconnect switch 2	
Status 4_3	24716	190568	0	24716	1236	Disconnect switch 3	
Status 5	120000	0	0	120000	6000	Disconnect switch 4	
Status 6	240000	0	0	0	4200	Dismantle shunts	

Short-circuit pieces in status 2 are closed by bolt, and in status 3 they are closed by the mechanical open/close device.

Shunts are normally used for pot startup to reduce the impact on pots by current and voltage, and the current bypassed by shunts here is assumed as 50%.

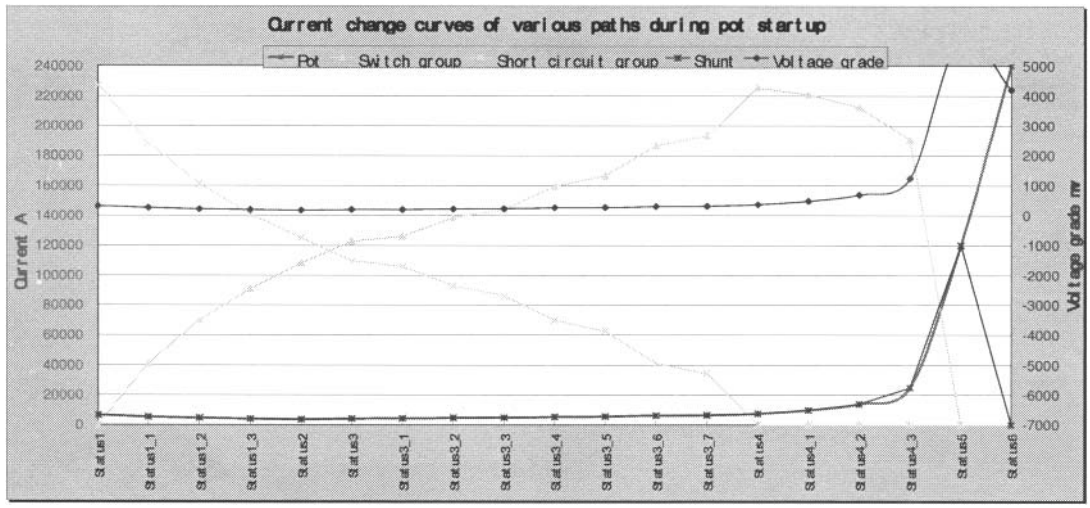


Figure 7 Current Change Curves of All Paths during Pot Startup

It's indicated by table 2 and figure 9: voltage of stopped pot is 305mv (status 1), 89.8% current is bypassed by short circuit piece group; when current diversion switch is all connected (status 2), voltage reduces to 172mv, 43.7% current is bypassed by switch group; subsequently, loosen the bolt at short circuit mouth, and open short circuit piece group (status 4), the current bypassed by short circuit mouth group reduces from 50.6% to 0%, and the current bypassed by switch group increases to 88.4%; finally, when switch group is disconnected in turn, the current bypassed by switch group reduces to 0%, and the current bypassed by pot increases to 50.0%, voltage increases to 6000mv (impact voltage); after running for certain time, as shunt temperature keeps increasing and the current bypassed by it keeps reducing, dismantle the shunts, pot is powered on 100%, and current diversion from short circuit piece to pot is finished.

From status 3 to status 4, i.e. the short circuit piece group status changes from closed to opened, voltage only changes within lower and small range of 194~347mv, therefore, the arcing energy at short circuit mouth is effectively controlled, and the operation security at short circuit mouth is also ensured.

Conclusions

By adding current switch bypass, the electric potential, current and their change gradients at short circuit mouth before and after the short circuit mouth is opened and closed can be reduced, so as to reduce effectively the potential energy at the short circuit mouth.

The short circuit mouth mechanical open/close device can open/close the short circuit mouth quickly, simultaneously, non-manually and with remote control, shorten the arcing duration of the short circuit mouth during open and close period, and also increase security greatly.

Pot startup/stoppage technology with full potline current amperage can bring for enterprise social and economic benefits on energy saving, production increase and emission decrease.

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