Синхронный генератор

Вариант 30

Проектное задание:

$$P\_{ном}≝400$$

$$U\_{ном}≝6000$$

$$n\_{ном}≝500$$

$$f≝50$$

$$cosφ\_{ном}≝0,9$$

$$k\_{E}≝1,06$$

$$h≝400$$

$$\frac{M\_{max}}{M\_{ном}}=2,0$$

Номинальные величины

$$U\_{номф}≝\frac{U\_{ном}}{\sqrt{3}}$$

1.

$$U\_{номф}=3464$$

2.

$$η\_{ном}≝0,929$$

$$S`\_{ном}≝\frac{P\_{ном}}{cosφ\_{ном}⋅η\_{ном}}$$

$$S`\_{ном}=478$$

$$I\_{номф}≝\frac{S`\_{ном}⋅10^{3}}{\sqrt{3}⋅U\_{ном}}$$

3.

$$I\_{номф}=46$$

4.

$$p≝\frac{60⋅f}{n\_{ном}}$$

$$p=6$$

5.

$$S`≝k\_{E}⋅S`\_{ном}$$

$$S`=507$$

Размеры статора

6.

$$D≝0,83$$

7.

$$K\_{D}≝1,28$$

$$D\_{a}≝K\_{D}⋅D$$

$$D\_{a}=1,062$$

8.

$$τ≝\frac{π⋅D}{2⋅p}$$

$$τ=0,217$$

9.

$$A`≝400⋅10^{2}$$

$$B\_{δном}≝0,85$$

$$α\_{δ}≝0,66$$

$$k\_{B}≝1,16$$

$$k`\_{об1}≝0,92$$

$$l\_{δ}≝\frac{6,1⋅S`⋅10^{3}}{α\_{δ}⋅k\_{B}⋅k`\_{об1}⋅A`⋅B\_{δном}⋅D^{2}⋅n\_{ном}}$$

$$α\_{δ}⋅k\_{B}=0,766$$

$$l\_{δ}=0,375$$

$$λ≝\frac{l\_{δ}}{τ}$$

10.

$$λ=1,726$$

11.

$$l\_{1}≝1,05⋅l\_{δ}$$

$$l\_{1}=0,39$$

12.

$$b\_{k}≝0,01$$

$$l`\_{пак}≝0,05$$

$$n`\_{k}≝\frac{l\_{1}-l`\_{пак}}{l`\_{пак}+b\_{k}}$$

$$n`\_{k}=5,729$$

$$n\_{k}≝6$$

13.

$$l\_{пак}≝\frac{l\_{1}-n\_{k}⋅b\_{k}}{n\_{k}+1}$$

$$l\_{пак}=0,048$$

14.

$$l\_{ст1}≝l\_{пак}⋅\left(n\_{k}+1\right)$$

$$l\_{ст1}=0,334$$

Зубцовая зона статора. Сегментировка

15.

$$a≝1$$

16.

$$t\_{Z1min}≝0,02$$

$$t\_{Z1max}≝0,025$$

17.

$$Z\_{1max}≝\frac{π⋅D}{t\_{Z1min}}$$

$$Z\_{1max}=130$$

$$Z\_{1min}≝\frac{π⋅D}{t\_{Z1max}}$$

18.

$$Z\_{1min}=104$$

19.

$$Z`\_{1}≝108$$

$$m≝3$$

$$t\_{Z1}≝\frac{π⋅D}{Z`\_{1}}$$

$$t\_{Z1}=0,024$$

20.

$$Z\_{1}≝108$$

$$q\_{1}≝\frac{Z\_{1}}{2⋅p⋅m}$$

$$q\_{1}=3$$

$$u`\_{п}≝\frac{π⋅a⋅D⋅A`}{Z\_{1}⋅I\_{номф}}$$

$$\frac{415}{400}=1,038$$

$$u`\_{п}=20,978$$

$$u\_{п}≝21$$

$$A≝\frac{Z\_{1}⋅u\_{п}⋅I\_{номф}}{π⋅a⋅D}$$

$$A=40041,006$$

$$H≝0,74$$

$$s`\_{ст}≝\frac{π⋅D}{H}$$

$$s\_{ст}≝4$$

$$s`\_{ст}=3,524$$

$$Z\_{s}≝\frac{Z\_{1}}{s\_{ст}}$$

$$H≝D\_{a}⋅sin\left(\frac{π}{s\_{ст}}\right)=0,751$$

$$Z\_{s}=27$$

Пазы и обмотка статора

21.

$$b`\_{п1}≝0,5⋅t\_{Z1}$$

$$b`\_{п1}=0,012$$

$$AJ`\_{1}≝2400⋅10^{8}$$

22.

$$J`\_{1}≝\frac{AJ`\_{1}}{A}$$

$$J`\_{1}=5,994⋅10^{6}$$

$$q`\_{еф}≝\frac{I\_{номф}}{a⋅J`\_{1}}$$

$$q`\_{еф}=7,68⋅10^{-6}$$

$$n\_{ш}≝1$$

$$n\_{в}≝1$$

$$n\_{ел}≝n\_{ш}⋅n\_{в}$$

$$n\_{ел}=1$$

$$q`\_{ел}≝\frac{q`\_{еф}}{n\_{ел}}$$

$$q`\_{ел}=7,68⋅10^{-6}$$

23.

$$δ\_{ізп}≝4,7$$

толщина изоляции

Ширина голого проводника

$$b`\_{1із}≝b`\_{п1}⋅10^{3}-δ\_{ізп}$$

$$b`\_{1із}=7,4$$

$$b\_{гол}≝b`\_{1із}-0,5$$

$$b\_{гол}=6,87$$

24.

Размеры проводников обмотки:

провод ПСД

$$a\_{1}≝1,12$$

$$b\_{1}≝7,1$$

$$a\_{1із}≝1,62$$

$$b\_{1із}≝7,6$$

$$q\_{ел}≝7,737⋅10^{-6}$$

$$q\_{еф}≝q\_{ел}⋅n\_{ел}$$

$$q\_{еф}=7,737⋅10^{-6}$$

25.

$$δ\_{рщ}≝0,05$$

$$δ\_{ш}≝0,2$$

$$b\_{п1}≝n\_{ш}⋅b\_{1із}+δ\_{ізп}+δ\_{рщ}+δ\_{ш}$$

$$b\_{п1}=12,55$$

26.

$$h\_{k}≝4$$

$$Σδ\_{із}≝b\_{п1}$$

$$δ\_{рв}≝0,5⋅n\_{в}⋅u\_{п}$$

$$δ\_{рв}=10,5$$

$$δ\_{в}≝δ\_{ш}$$

$$h\_{п1}≝u\_{п}⋅n\_{в}⋅a\_{1із}+Σδ\_{із}+h\_{k}+δ\_{рв}+δ\_{в}$$

$$h\_{п1}=61$$

$$\frac{h\_{п1}}{b\_{п1}}=4,8821$$

27.

$$J\_{1}≝\frac{I\_{номф}}{a⋅q\_{еф}}$$

$$J\_{1}=5,95⋅10^{6}$$

28.

$$k\_{с}≝0,97$$

$$B`\_{Z1}≝\frac{B\_{δном}⋅t\_{Z1}⋅l\_{δ}}{\left(t\_{Z1}-b\_{п1}⋅10^{-3}\right)⋅l\_{ст1}⋅k\_{с}}$$

$$B`\_{Z1}=2,05$$

29.

$$h\_{a}≝\frac{D\_{a}-D}{2}-h\_{п1}⋅10^{-3}$$

$$l\_{δ}=0,375$$

$$h\_{a}=0,055$$

$$l\_{ст1}=0,3338$$

$$B\_{a}≝\frac{α\_{δ}⋅B\_{δном}⋅τ⋅l\_{δ}}{2⋅h\_{a}⋅l\_{ст1}⋅k\_{с}}$$

$$B\_{a}=1,29$$

$$λ\_{із}≝2,2⋅10^{-5}$$

30.

$$k\_{ф}≝1,1$$

$$Δυ\_{із}≝\frac{J\_{1}⋅A⋅k\_{ф}}{4,2⋅10^{11}}⋅\frac{t\_{Z1}}{2⋅\left(b\_{п1}+h\_{п1}-h\_{k}\right)}⋅\left(\frac{0,5⋅δ\_{ізп}}{λ\_{із}}\right)$$

$$Δυ\_{із}=11,524$$

$$δ\_{ізп}=4,7$$

$$Δυ`\_{із}≝\frac{Δυ\_{із}}{0,5⋅δ\_{ізп}⋅10^{-3}}$$

31.

$$Δυ`\_{із}=4903,85$$

$$w\_{1}≝2⋅p⋅q\_{1}⋅\frac{u\_{п}}{2}⋅\frac{1}{a}$$

32.

$$w\_{1}=378$$

33.

$$τ\_{п}≝3⋅q\_{1}$$

$$τ\_{п}=9$$

$$y`\_{1}≝\left(0,86\right)⋅τ\_{п}$$

$$y`\_{1}=7,7$$

$$y\_{1}≝8$$

$$k\_{y}≝sin\left(\frac{π}{2}⋅\frac{y\_{1}}{τ\_{п}}\right)$$

34.

$$k\_{y}=0,985$$

$$k\_{p}≝\frac{0,5}{q\_{1}⋅sin\left(\frac{π}{6⋅q\_{1}}\right)}$$

35.

$$k\_{p}=0,96$$

36.

$$k\_{об1}≝k\_{y}⋅k\_{p}$$

$$k\_{об1}=0,945$$

Воздушный зазор и полюсы ротора

37.

$$x`\_{d}≝1,3$$

$$B\_{δ0}≝0,95⋅B\_{δном}$$

$$B\_{δ0}=0,808$$

$$δ≝0,3⋅\frac{A}{B\_{δ0}}⋅\frac{τ}{x`\_{d}}⋅10^{-6}$$

$$δ=0,002$$

38.

$$δ\_{m}≝1,5⋅δ$$

$$δ\_{m}=0,004$$

$$δ`≝δ+\frac{\left(δ\_{m}-δ\right)}{3}$$

$$δ`=0,003$$

39.

$$α≝0,72$$

$$b\_{p}≝α⋅τ$$

$$b\_{p}=0,156$$

$$R\_{p}≝\frac{D}{2+8⋅D⋅\left(\frac{δ\_{m}-δ}{b\_{p}^{2}}\right)}$$

40.

$$R\_{p}=0,355$$

41.

$$h\_{p}≝0,032$$

42.

$$l\_{p}≝l\_{1}-0,01$$

$$l\_{p}=0,38$$

$$l\_{m}≝l\_{p}=0,38$$

43.

$$l\_{f}≝0,02$$

$$l`\_{m}≝l\_{m}+l\_{f}$$

$$l`\_{m}=0,4$$

44.

$$h\_{m}≝0,016+0,186⋅\sqrt[4]{τ}$$

$$h\_{m}=0,143$$

45.

$$k≝7$$

$$σ\_{m}≝1+k⋅\left(\frac{0,35⋅δ}{τ^{2}}\right)$$

$$σ\_{m}=1,129$$

46.

$$B\_{m}≝1,4$$

$$k\_{ср}≝0,95$$

$$b\_{m}≝\frac{α\_{δ}⋅B\_{δном}⋅τ⋅l\_{δ}}{B\_{m}⋅k\_{ср}⋅l`\_{m}}⋅σ\_{m}$$

$$b\_{m}=0,096$$

$$υ\_{p}≝\frac{π⋅D⋅n\_{ном}}{60}$$

$$υ\_{p}=21,7$$

47.

$$Δl\_{c}≝0,12$$

$$l\_{j}≝l\_{m}+Δl\_{c}$$

$$l\_{j}=0,5$$

48.

$$B\_{j}≝1,2$$

$$h\_{j}≝\frac{α\_{δ}⋅B\_{δном}⋅τ⋅l\_{δ}}{2⋅B\_{j}⋅l\_{j}}⋅σ\_{m}$$

$$h\_{j}=0,043$$

Пусковая обмотка

49.

$$N\_{c}≝8$$

50.

$$q`\_{c}≝\frac{0,35⋅τ⋅A}{N\_{c}⋅J\_{1}}$$

$$\frac{40000⋅0,25⋅0,217}{5,95⋅10^{6}⋅10}=3,6471⋅10^{-5}$$

$$q`\_{c}=6,4⋅10^{-5}$$

51.

$$d`\_{c}≝1,13⋅\sqrt{q`\_{c}}$$

$$\frac{0,3⋅0,236⋅44000}{6⋅4,6⋅10^{6}}=0,000113$$

$$d`\_{c}=0,009$$

$$d\_{c}≝0,009$$

$$q\_{c}≝65$$

52.

$$z≝0,003$$

$$t\_{Z2}≝\frac{b\_{p}-d\_{c}-2⋅z}{N\_{c}-1}$$

$$t\_{Z2}=0,0202$$

53.

$$0,8⋅t\_{Z1}=0,01931$$

$$0,8⋅t\_{Z1}\leq t\_{Z2}$$

$$\left(N\_{c}-1\right)⋅\left(1-\frac{t\_{Z2}}{t\_{Z1}}\right)=1,141$$

54.

$$d\_{s}≝d\_{c}+0,0001$$

$$d\_{s}=0,0091$$

$$b\_{s}≝4$$

$$h\_{s}≝2$$

55.

$$l\_{c}≝l\_{p}+0,34⋅τ$$

$$l\_{c}=0,46$$

56.

$$b\_{кз}≝1,0$$

$$q`\_{кз}≝b\_{кз}⋅0,5⋅N\_{c}⋅q\_{c}$$

$$q`\_{кз}=260$$

Выбираем прямоугольную медь

$$4$$

$$х$$

$$65$$

$$q\_{кз}≝259,5$$

$$h\_{j}=0,043$$

Расчёт магнитной цепи

$$k\_{B}=1,16$$

$$E`\_{1}≝\left[\begin{array}{c}0,5\\1\\1,1\\1,2\\1,3\end{array}\right]$$

$$k\_{об1}≝0,915$$

$$k\_{B}≝1,13$$

$$E\_{1}≝U\_{номф}⋅E`\_{1}$$

$$E\_{1}=\left[\begin{array}{c}1732,0508\\3464,1016\\3810,5118\\4156,9219\\4503,3321\end{array}\right]$$

$$Φ`≝\frac{E\_{1}}{4⋅k\_{B}⋅f⋅w\_{1}⋅k\_{об1}}$$

57.

$$k\_{об1}=0,915$$

$$4⋅k\_{B}⋅f⋅w\_{1}⋅k\_{об1}=78166,62$$

$$w\_{1}=378$$

$$Φ=0,128⋅10^{-4}⋅\vec{E\_{1}}$$

$$Φ`=\left[\begin{array}{c}0,0222\\0,0443\\0,0487\\0,0532\\0,0576\end{array}\right]$$

$$\frac{δ\_{m}}{δ}=1,5$$

$$\frac{δ}{τ}=0,011$$

$$α=0,72$$

$$a\_{δ}≝0,68$$

$$γ`≝\frac{\left(\frac{b\_{k}}{δ}\right)^{2}}{5+\frac{b\_{k}}{δ}}$$

$$δ=0,002$$

58.

$$4⋅1,15⋅50⋅360⋅0,915=75762$$

$$γ`=1,793$$

$$b`\_{k}≝γ`⋅δ$$

$$b`\_{k}=0,00446$$

$$l\_{δ}≝l\_{1}-b`\_{k}⋅n\_{k}+2⋅δ`$$

$$\frac{0,338⋅10^{-4}}{α\_{δ}⋅τ⋅l\_{δ}}=0,000632$$

$$l\_{δ}=0,373$$

$$B`\_{δ}≝\frac{Φ`}{α\_{δ}⋅τ⋅l\_{δ}}$$

59.

$$B\_{δ}=2,4⋅10^{-4}⋅\vec{E\_{1}}$$

$$B`\_{δ}=\left[\begin{array}{c}0,4144\\0,8289\\0,9118\\0,9946\\1,0775\end{array}\right]$$

$$k\_{δ1}≝\frac{t\_{Z1}⋅10^{3}+10^{3}⋅δ`}{\left(t\_{Z1}⋅10^{3}-b\_{п1}\right)+10^{3}⋅δ`}$$

60.

$$k\_{δ1}=1,87$$

$$k\_{δ2}≝\frac{t\_{Z2}⋅10^{3}+10⋅δ`}{t\_{Z2}⋅10^{3}-b\_{s}+10^{3}⋅δ`}$$

61.

$$k\_{δ2}=1,059$$

62.

$$k\_{δ}≝k\_{δ1}⋅k\_{δ2}$$

$$k\_{δ}=1,98$$

$$μ\_{0}≝1,256⋅10^{-6}$$

$$\frac{1}{μ\_{0}}⋅2,4⋅10^{-4}⋅k\_{δ}⋅δ=0,9388$$

63.

$$F`\_{δ}≝\frac{1}{μ\_{0}}⋅B`\_{δ}⋅δ⋅k\_{δ}$$

$$F\_{δ}=0,6328⋅\vec{E\_{1}}$$

$$F`\_{δ}=\left[\begin{array}{c}1621,2044\\3242,4088\\3566,6497\\3890,8905\\4215,1314\end{array}\right]$$

$$t\_{Z1}≝\frac{π⋅\left(D+\frac{2⋅h\_{п1}}{3}⋅10^{-3}\right)}{Z\_{1}}$$

64.

$$D=0,83$$

$$t\_{Z1}=0,0253$$

$$h\_{п1}=61,27$$

$$b\_{Z1}≝t\_{Z1}-b\_{п1}⋅10^{-3}$$

$$b\_{Z1}=0,0128$$

$$k\_{п}≝\frac{t\_{Z1}⋅l\_{1}}{l\_{ст1}⋅k\_{с}⋅b\_{Z1}}-1=1,4104$$

$$l\_{ст1}=0,334$$

$$B\_{Z1}≝\frac{B`\_{δ}⋅t\_{Z1}⋅l\_{δ}}{b\_{Z1}⋅l\_{ст1}⋅k\_{с}}$$

65.

$$\frac{2,4⋅10^{-4}⋅t\_{Z1}⋅l\_{δ}}{b\_{Z1}⋅l\_{ст1}⋅k\_{с}}=0,00055$$

$$B`\_{Z1}=4,7⋅10^{-3}⋅\vec{E\_{1}}$$

$$t\_{Z1}=0,025$$

66.

сталь марки 1511

$$B\_{Z1}=\left[\begin{array}{c}0,9458\\1,8917\\2,0808\\2,27\\2,4592\end{array}\right]$$

$$H\_{Z1}≝\left[\begin{matrix}261&7600&22000&26000&49000\end{matrix}\right]$$

$$F`\_{Z1}≝h\_{п1}⋅10^{-3}⋅H\_{Z1}$$

$$F`\_{Z1}$$

$$\frac{0,128⋅10^{-4}}{2⋅l\_{ст1}⋅h\_{a}⋅k\_{с}}=0,00036$$

$$B`\_{a}≝\frac{Φ`}{2⋅l\_{ст1}⋅h\_{a}⋅k\_{с}}$$

67.

$$B\_{a}=3,9⋅10^{-4}⋅E\_{1}$$

$$B`\_{a}=\left[\begin{array}{c}0,623\\1,246\\1,3706\\1,4952\\1,6198\end{array}\right]$$

68.

$$L\_{a}≝\frac{π⋅\left(D\_{a}-h\_{a}\right)}{4⋅p}$$

$$h\_{a}=0,0549$$

$$L\_{a}=0,132$$

$$ξ≝\left[\begin{matrix}0,62&0,38&0,33&0,3&0,28\end{matrix}\right]$$

cталь марки 1511 П1.3

$$H\_{a}≝\left[\begin{matrix}177&1340&3370&7100&18000\end{matrix}\right]$$

$$F`\_{a}≝\vec{\vec{ξ}⋅L\_{a}⋅\vec{H\_{a}}}$$

$$F\_{a}=\vec{13⋅10^{-2}⋅ξ⋅H\_{a}}$$

$$F`\_{a}$$

$$D=0,83$$

69.

$$h\_{Z2}≝h\_{s}⋅10^{-2}+d\_{s}⋅10^{-2}$$

$$δ=0,00249$$

$$h\_{Z2}=0,02009$$

$$h\_{Z2}=0,0201$$

$$d\_{s}=0,009$$

$$b\_{Z2}≝\frac{D-2⋅δ-\frac{2}{3}⋅h\_{Z2}}{D-2⋅δ}⋅t\_{Z2}-0,94⋅d\_{s}$$

$$t\_{Z2}=0,02$$

70.

$$d\_{s}=0,0091$$

$$b\_{Z2}=0,0113$$

$$B`\_{Z2}≝\frac{B`\_{δ}⋅t\_{Z2}⋅l\_{δ}}{b\_{Z2}⋅l\_{p}⋅k\_{ср}}$$

$$k\_{п2}≝\frac{t\_{Z2}⋅l\_{p}}{l\_{p}⋅k\_{с}⋅b\_{Z2}}-1=0,8395$$

71.

$$\frac{4,49⋅10^{-4}⋅t\_{Z2}⋅l\_{δ}}{b\_{Z2}⋅l\_{p}⋅k\_{ср}}=0,0008$$

$$B\_{Z2}=4,4⋅10^{-4}⋅E\_{1}$$

$$B`\_{Z2}=\left[\begin{array}{c}0,7562\\1,5124\\1,6636\\1,8148\\1,9661\end{array}\right]$$

72.

Ст3 сталь для зубцов П 1.4

$$H\_{Z2}≝\left[\begin{matrix}375&3050&5580&11900&22500\end{matrix}\right]$$

$$F`\_{Z2}≝h\_{Z2}⋅H\_{Z2}$$

$$F\_{Z2}=2,01⋅10^{-2}⋅H\_{Z2}$$

$$F`\_{Z2}$$

$$λ\_{ml}≝\frac{0,55⋅h\_{m}⋅10^{-6}}{τ-b\_{m}-\frac{π}{2⋅p}⋅\left(h\_{m}+2⋅h\_{p}+2⋅δ\right)}$$

73.

$$λ\_{ml}=1,197⋅10^{-6}$$

74.

$$c\_{p}≝\frac{b\_{p}-b\_{m}}{2}$$

$$c\_{p}=0,0302$$

$$d\_{t}≝h\_{p}+δ-\frac{b\_{p}^{2}}{4⋅D}$$

$$d\_{t}=0,0271$$

$$a`\_{p}≝τ-b\_{p}-\frac{π⋅d\_{t}}{p}$$

$$a`\_{p}=0,0466$$

$$λ\_{pl}≝\left(1,4⋅\left(\frac{d\_{t}}{a`\_{p}}-0,25\right)+0,55⋅\left(\frac{c\_{p}}{a`\_{p}}+0,2\right)-0,4⋅\left(\frac{c\_{p}}{a`\_{p}}-0,5\right)^{2}\right)⋅10^{-6}$$

$$λ\_{pl}=9,2⋅10^{-7}$$

$$b\_{m}=0,096$$

$$l`\_{m}=0,404$$

$$λ\_{mb}≝0,37⋅\frac{b\_{m}}{l`\_{m}}⋅10^{-6}$$

75.

$$λ\_{mb}=8,808⋅10^{-8}$$

76.

$$λ\_{mσ}≝λ\_{ml}+λ\_{pl}+λ\_{mb}$$

$$λ\_{mσ}=2,21⋅10^{-6}$$

$$\frac{2710,79}{2186,477}=1,2398$$

77.

$$F`\_{δZa}≝F`\_{δ}+F`\_{Z1}+F`\_{a}+F`\_{Z2}$$

$$F`\_{δZa}=\left[\begin{array}{c}1659,2\\3836,49\\5173,36\\6003,89\\8334,07\end{array}\right]$$

78.

$$Φ`\_{σ}≝4⋅λ\_{mσ}⋅l`\_{m}⋅F`\_{δZa}$$

$$Φ\_{σ}=3,5631⋅10^{-6}⋅F`\_{δZa}$$

$$Φ`\_{σ}=\left[\begin{array}{c}0,0059\\0,0137\\0,0184\\0,0214\\0,0297\end{array}\right]$$

79.

$$Φ`\_{m}≝eval\left(Φ`+Φ`\_{σ}\right)$$

$$Φ\_{m}=0,128⋅10^{-4}⋅E\_{1}+3,5631⋅10^{-6}⋅F\_{δZa}$$

$$Φ`\_{m}=\left[\begin{array}{c}0,0281\\0,058\\0,0672\\0,0746\\0,0873\end{array}\right]$$

80.

$$k\_{ср}≝0,95$$

$$B\_{m}=\frac{Φ+Φ\_{σ}}{l`\_{m}⋅b\_{m}⋅k\_{ср}}=\frac{0,128⋅10^{-4}⋅E\_{1}+3,5631⋅10^{-6}⋅F`\_{δZa}}{l`\_{m}⋅b\_{m}⋅k\_{ср}}$$

$$l`\_{m}⋅b\_{m}⋅k\_{ср}=0,03687$$

$$B\_{m}=0,779⋅10^{-3}⋅E\_{1}+0,743⋅10^{-4}⋅F`\_{δZa}$$

$$B`\_{m}≝eval\left(\frac{Φ`+Φ`\_{σ}}{l`\_{m}⋅b\_{m}⋅k\_{ср}}\right)$$

$$B`\_{m}=\left[\begin{array}{c}0,7614\\1,5729\\1,8223\\2,0228\\2,3682\end{array}\right]$$

81.

$$h\_{mp}≝h\_{m}+h\_{p}$$

$$h\_{mp}=0,175$$

$$H\_{m}≝\left[\begin{matrix}351&1835&4350&11780&29420\end{matrix}\right]$$

$$H\_{m}≝\left[\begin{array}{c}351\\1835\\4350\\11780\\29420\end{array}\right]$$

$$F\_{m}≝h\_{mp}⋅H\_{m}$$

$$F\_{m}=\left[\begin{array}{c}61,422\\321,109\\761,213\\2061,4\\5148,25\end{array}\right]$$

82.

$$F\_{δmj}≝250⋅B`\_{m}$$

$$F\_{δmj}=\left[\begin{array}{c}190,354\\393,227\\455,582\\505,702\\592,058\end{array}\right]$$

83.

$$B`\_{j}≝eval\left(\frac{Φ`+Φ`\_{σ}}{2⋅l\_{j}⋅h\_{j}⋅k\_{ср}}\right)$$

$$B\_{j}=\frac{0,319⋅10^{-4}⋅E\_{1}+3,041⋅10^{-6}⋅F`\_{δZa}}{2⋅l\_{j}⋅h\_{j}⋅k\_{ср}}$$

$$B`\_{j}=\left[\begin{array}{c}0,687\\1,419\\1,644\\1,825\\2,137\end{array}\right]$$

$$D=0,83$$

$$L\_{j}≝\frac{π⋅\left(D-2⋅δ-2⋅h\_{mp}-h\_{j}\right)}{4⋅p}$$

84.

$$δ=0,0025$$

$$h\_{j}=0,0427$$

$$L\_{j}=0,057$$

$$H\_{j}≝\left[\begin{matrix}525&1670&3100&5550&10700\end{matrix}\right]$$

$$H\_{j}≝\left[\begin{array}{c}525\\1670\\3100\\5550\\10700\end{array}\right]$$

$$F\_{j}≝L\_{j}⋅H\_{j}$$

$$F\_{j}=\left[\begin{array}{c}29,712\\94,514\\175,445\\314,103\\605,568\end{array}\right]$$

$$F`\_{j}=0,031⋅H\_{j}$$

85.

$$F\_{mj}≝F\_{m}+F\_{δmj}+F\_{j}$$

$$F\_{mj}=\left[\begin{array}{c}281,489\\808,85\\1392,239\\2881,205\\6345,876\end{array}\right]$$

86.

$$F`\_{f0}≝F`\_{δZa}+F\_{mj}$$

$$F\_{f0}=F\_{δ}+F\_{Z1}+F\_{a}+F\_{Z2}+F\_{m}+F\_{δmj}+F\_{j}$$

$$F`\_{f0}=\left[\begin{array}{c}1940,691\\4645,34\\6565,598\\8885,097\\14679,947\end{array}\right]$$

$$Φ\_{m``}≝\frac{Φ`\_{m}}{0,0443}$$

$$F\_{f0``}≝\frac{F`\_{f0}}{4628,851}$$

$$Φ\_{m``}=\left[\begin{array}{c}0,6336\\1,309\\1,5165\\1,6834\\1,9708\end{array}\right]$$

$$F\_{f0``}=\left[\begin{array}{c}0,4193\\1,0036\\1,4184\\1,9195\\3,1714\end{array}\right]$$

$$F\_{δza``}≝\frac{F`\_{δZa}}{4628,851}$$

$$Φ\_{σ``}≝eval\left(\frac{Φ`\_{σ}}{0,0443}\right)$$

$$F\_{δza``}=\left[\begin{array}{c}0,3584\\0,8288\\1,1176\\1,2971\\1,8005\end{array}\right]$$

$$Φ\_{σ``}=\left[\begin{array}{c}0,1335\\0,3086\\0,4161\\0,4829\\0,6703\end{array}\right]$$

$$F\_{mj``}≝\frac{F\_{mj}}{4628,851}$$

$$F``≝\vec{\frac{F`\_{δZa}}{F`\_{δ}}}$$

$$F```≝\left[\begin{array}{c}0\\1,0325\\1,2398\\1,3842\\1,7142\\2,2901\end{array}\right]$$

$$F\_{mj``}=\left[\begin{array}{c}0,0608\\0,1747\\0,3008\\0,6224\\1,3709\end{array}\right]$$

$$F``=\left[\begin{array}{c}1,0234\\1,1832\\1,4505\\1,5431\\1,9772\end{array}\right]$$

$$F\_{mj```}≝\left[\begin{array}{c}0\\0,0608\\0,1747\\0,3005\\0,6222\\1,3704\end{array}\right]$$

$$Φ\_{m```}≝\left[\begin{array}{c}0\\0,59\\1,218\\1,4\\1,56\\1,8\end{array}\right]$$

$$Φ\_{σ```}≝\left[\begin{array}{c}0\\0,0908\\0,218\\0,3065\\0,3618\\0,5236\end{array}\right]$$

$$E\_{1```}≝\left[\begin{array}{c}0\\0,5\\1\\1,1\\1,2\\1,3\end{array}\right]$$

$$F\_{δza```}≝\left[\begin{array}{c}0\\0,3232\\0,7762\\1,091\\1,2878\\1,8639\end{array}\right]$$

$$F\_{f0```}≝\left[\begin{array}{c}0\\0,555\\1,325\\1,866\\2,528\\4,173\end{array}\right]$$





$$Е\_{норм}≝\left[\begin{array}{c}1\\1,21\\1,33\\1,44\\1,46\\1,51\end{array}\right]$$

$$F\_{fнорм}≝\left[\begin{array}{c}1\\1,5\\2\\2,5\\3\\3,5\end{array}\right]$$



Параметры обмотки статора для установившегося режима

88.

$$B\_{1}≝0,045$$

$$s\_{i}≝0,0065$$

$$β≝0,8$$

$$t\_{Z1}=0,0253$$

$$l\_{л}≝\frac{π⋅\left(D+h\_{п1}⋅10^{-3}\right)⋅β}{2⋅p⋅\sqrt{1-\left(\frac{b\_{1}⋅10^{-3}+s\_{i}}{t\_{Z1}}\right)^{2}}}+h\_{п1}⋅10^{-3}+2⋅B\_{1}$$

$$b\_{1}=7,1$$

$$h\_{п1}=61,27$$

$$D=0,83$$

$$l\_{л}=0,373$$

87.

$$l\_{cp1}≝2⋅\left(l\_{1}+l\_{л}\right)$$

$$l\_{cp1}=1,533$$

$$r1\_{20}≝\frac{w\_{1}⋅l\_{cp1}}{57⋅10^{6}⋅q\_{еф}⋅a}$$

$$q\_{еф}=7,737⋅10^{-6}$$

89.

$$r1\_{20}=1,3136$$

$$r1\_{75}≝1,2⋅r1\_{20}$$

$$r1\_{75}=1,576$$

$$r1`\_{20}≝r1\_{20}⋅\frac{I\_{номф}}{U\_{номф}}=0,0175$$

90.

$$U\_{номф}=3464,1016$$

$$Z\_{б}≝\frac{U\_{номф}}{I\_{номф}}$$

$$I\_{номф}=46,0352$$

$$Z\_{б}=75,249$$

$$\frac{U\_{номф}}{I\_{номф}}=75,249$$

$$r`1\_{75}≝\frac{r1\_{75}}{Z\_{б}}$$

$$r`1\_{75}=0,021$$

92.

$$k`\_{β}≝\frac{1+3⋅β}{4}$$

$$k`\_{β}=0,85$$

$$k\_{β}≝\frac{1+3⋅k`\_{β}}{4}$$

$$k\_{β}=0,89$$

$$h\_{2}≝6,33$$

$$h\_{0}≝0,67$$

$$h\_{1}≝0,785$$

$$b\_{п1}=12,55$$

$$λ\_{п}≝\frac{h\_{2}-h\_{0}}{3⋅b\_{п1}⋅10^{-1}}⋅k\_{β}+\frac{h\_{1}}{b\_{п1}}⋅k`\_{β}+\frac{h\_{0}}{4⋅b\_{п1}}$$

$$λ\_{п}=1,4$$

$$\frac{b\_{п1}⋅10^{-3}}{δ`⋅k\_{δ}}=2,19$$

$$λ`\_{k}≝0,26$$

$$k\_{δ}=1,976$$

$$При$$

$$δ`=0,0029$$

$$λ\_{к}≝\left(α⋅λ`\_{k}+\left(0,22+0,32⋅\sqrt{\frac{t\_{Z1}-b\_{п1}⋅10^{-3}}{b\_{п1}⋅10^{-3}}}\right)⋅\left(1-α\right)\right)⋅k`\_{β}$$

$$λ\_{к}=0,288$$

$$λ\_{пк}≝λ\_{п}+λ\_{к}$$

$$λ\_{пк}=1,689$$

$$λ\_{л}≝0,34⋅\frac{q\_{1}}{l\_{δ}}⋅\left(l\_{л}-0,64⋅β⋅τ\right)$$

93.

$$λ\_{л}=0,715$$

$$l\_{δ}=0,3728$$

$$q\_{1}=3$$

$$λ\_{д}≝0,03⋅\frac{\left(τ⋅α\_{δ}\right)}{δ`⋅k\_{δ}⋅q\_{1}}$$

94.

$$β=0,8$$

$$τ=0,2173$$

$$λ\_{д}=0,25$$

$$x\_{σ}≝15,8⋅\frac{f}{100}⋅\left(\frac{w\_{1}}{100}\right)^{2}⋅\frac{l\_{δ}}{p⋅q\_{1}}⋅\left(λ\_{пк}+λ\_{л}+λ\_{д}\right)$$

91.

$$x\_{σ}=6,205$$

95.

$$x`\_{σ}≝\frac{x\_{σ}}{Z\_{б}}$$

$$δ=0,0025$$

$$x`\_{σ}=0,082$$

$$n≝0,01⋅τ=0,0022$$

96.

$$k\_{ad}≝0,85$$

$$F`\_{δ0}≝1621,2044$$

$$F\_{δ0}≝3242,4088$$

$$F\_{f0}≝1940,099$$

$$k\_{μ0}≝\frac{F\_{f0}}{F`\_{δ0}}=1,2$$

$$F\_{aном}≝0,45⋅m⋅\frac{\left(w\_{1}⋅k\_{об1}\right)}{p}⋅I\_{номф}$$

$$F\_{aном}=3582$$

$$x`\_{ad}≝\frac{k\_{ad}⋅F\_{aном}}{k\_{μ0}⋅F\_{δ0}}=0,785$$

$$x`\_{ad}=0,785$$

97.

$$k\_{aq}≝0,42$$

$$B\_{a}=1,2853$$

$$x`\_{aq}≝\frac{k\_{aq}⋅F\_{aном}}{k\_{μ0}⋅F\_{δ0}}⋅\frac{\left(1+k\_{δ}\right)}{2}$$

$$x`\_{aq}=0,577$$

98.

$$x`\_{d}≝x`\_{σ}+x`\_{ad}$$

$$x`\_{σ}=0,0825$$

$$x`\_{d}=0,867$$

99.

$$x`\_{q}≝x`\_{σ}+x`\_{aq}$$

$$x`\_{q}=0,659$$

Магнитодвижущая сила обмотки возбуждения при нагрузке

$$ψ≝0,9$$

100.

$$E\_{δ`}≝1,09$$

$$κ\_{q}≝0,6$$

$$k≝0,0026$$

$$κ`\_{d}≝0,92$$

$$κ\_{q`}≝\left[\begin{matrix}0,67&0,73&0,745\end{matrix}\right]$$

$$F\_{fб}≝3492,442$$

$$F\_{aном`}≝\frac{F\_{aном}}{F\_{fб}}$$

$$F`\_{aq`}≝κ\_{q`}⋅k\_{aq}⋅1,026=\left[\begin{matrix}0,289&0,315&0,321\end{matrix}\right]$$

101.

$$F\_{aном`}=1,026$$

$$F`\_{aq}≝κ\_{q}⋅k\_{aq}⋅F\_{aном`}$$

$$ψ`≝\left[\begin{matrix}0,73&0,47&0,35\end{matrix}\right]$$

$$F`\_{aq}=0,258$$

$$k`≝\left[\begin{matrix}0,0024&0,0023&0,0022\end{matrix}\right]$$

$$Ф\_{rd`}≝1,04$$

$$κ`\_{d`}≝\left[\begin{matrix}0,93&0,935&0,94\end{matrix}\right]$$

$$F\_{ad}≝\vec{κ`\_{d`}⋅k\_{ad}⋅F\_{aном`}⋅sin\left(ψ`\right)+k`⋅\left(\frac{τ}{δ}\right)⋅cos\left(ψ`\right)⋅F\_{aном`}}$$

$$E\_{rd`}≝Ф\_{rd`}=1,04$$

$$sin\left(ψ\right)=0,783$$

$$cos\left(ψ\right)=0,622$$

$$F\_{ad}=\left[\begin{matrix}0,701&0,553&0,466\end{matrix}\right]$$

$$F\_{rd`}≝1$$

$$F\_{ad}+F\_{rd`}=\left[\begin{matrix}1,701&1,553&1,466\end{matrix}\right]$$

$$F``\_{ad`}≝κ`\_{d}⋅k\_{ad}⋅F\_{aном`}⋅sin\left(ψ\right)+k⋅\left(\frac{τ}{δ}\right)⋅cos\left(ψ\right)⋅F\_{aном`}$$

102.

$$F``\_{ad`}=0,773$$

$$F``\_{ad`}+F\_{rd`}=1,773$$

$$Ф\_{σ`}≝0,51$$

$$Ф\_{m`}≝Ф\_{rd`}+Ф\_{σ`}=1,55$$

$$F\_{mj`}≝1$$

103.

$$F\_{fном`}≝F\_{rd`}+F``\_{ad`}+F\_{mj`}$$

$$F\_{fном`}=2,773$$

104.

$$F\_{fном}≝F\_{fном`}⋅F\_{fб}$$

$$F\_{fном}=9685,365$$

Обмотка возбуждения

$$δ\_{1}≝0,15⋅10^{-2}$$

$$δ``≝1,5⋅10^{-2}$$

105.

$$b\_{f}≝0,06⋅τ$$

$$b\_{f}=0,013$$

$$l\_{fcp}≝2⋅\left(l\_{m}-2⋅δ``\right)+π⋅\left(b\_{m}+2⋅δ\_{1}+b\_{f}\right)$$

$$l\_{fcp}=1,06$$

$$U\_{f}≝63$$

$$U\_{fном}≝65$$

106.

$$F`\_{fном}≝1,2⋅F\_{fном}$$

$$F`\_{fном}=11622,438$$

$$ρ\_{130}≝\frac{1}{39⋅10^{6}}$$

$$q\_{f}≝\frac{ρ\_{130}⋅2⋅p⋅F`\_{fном}⋅l\_{fcp}}{U\_{f}}$$

$$q\_{f}=6,016⋅10^{-5}$$

$$J\_{f}≝5,26⋅10^{6}$$

107.

$$I\_{fном}≝q\_{f}⋅J\_{f}$$

$$I\_{fном}=316,449$$

108.

$$w`\_{f}≝\frac{F\_{fном}}{I\_{fном}}$$

$$w`\_{f}=30,6064$$

$$w\_{f}≝32$$

$$δ\_{кп}≝1,0⋅10^{-2}$$

$$δ\_{п}≝0,03⋅10^{-2}$$

109.

$$a\_{f}≝\frac{h\_{m}-δ\_{кп}}{w\_{f}+1}-δ\_{п}$$

$$a\_{f}=0,0037$$

$$a\_{f}≝3,75⋅10^{-3}$$

$$q\_{f}≝59,14⋅10^{-6}$$

Таблица П3.2

$$a\_{f}$$

$$x$$

$$b\_{f}$$

$$b\_{f}≝16⋅10^{-3}$$

$$x1≝\frac{π⋅\left(D-2⋅δ-2⋅h\_{p}-2⋅h\_{m}\right)}{2⋅p}$$

110.

$$x1=0,124$$

$$J\_{f}≝\frac{I\_{fном}}{q\_{f}}$$

111.

$$J\_{f}=5,35⋅10^{6}$$

$$V\_{p}≝\frac{π⋅D⋅n\_{ном}}{60}$$

112.

$$h\_{m}=0,143$$

$$V\_{p}=21,729$$

$$Δυ\_{f}≝\frac{3⋅10^{-10}⋅\left(2,8+\frac{l\_{1}}{τ}\right)⋅b\_{f}⋅J\_{f}^{2}}{1,6+\sqrt{V\_{p}}}$$

$$Δυ\_{f}=101,23$$

113.

$$h\_{m}≝\left(a\_{f}+δ\_{п}\right)⋅\left(w\_{f}+1\right)+δ\_{кп}$$

$$h\_{m}=0,144$$

$$r\_{f130}≝ρ\_{130}⋅\frac{\left(2⋅p⋅w\_{f}⋅l\_{fcp}\right)}{q\_{f}}$$

114.

$$r\_{f130}=0,176$$

$$r\_{f15}≝r\_{f130}⋅\frac{39}{46}$$

$$r\_{f15}=0,1496$$

115.

$$υ≝130$$

$$ΔU\_{щ}≝2$$

$$U`\_{fном}≝I\_{fном}⋅r\_{f130}$$

$$U`\_{fном}=55,838$$

116.

$$k\_{з}≝\frac{U\_{fном}}{U`\_{fном}+ΔU\_{щ}}$$

$$U\_{fном}=65$$

$$k\_{з}=1,124$$

Параметры и постоянные времени

$$Σλ≝\left(λ\_{pl}+\frac{λ\_{ml}}{1,53}+\frac{λ\_{mb}}{2,65}\right)$$

117.

$$Σλ=1,737⋅10^{-6}$$

$$Φ`\_{δ}≝0,0443$$

$$x\_{f`}≝1,27⋅k\_{ad}⋅x`\_{ad}⋅\left(1+\frac{4⋅k\_{μ0}⋅F\_{δ0}⋅l`\_{m}⋅Σλ}{Φ`\_{δ}}\right)$$

$$x\_{f`}=1,055$$

118.

$$x\_{σf`}≝x\_{f`}-x`\_{ad}$$

$$x\_{σf`}=0,271$$

119.

$$\frac{t\_{Z2}}{τ}=0,093$$

$$k\_{b}≝0,42$$

$$N\_{c}=8$$

$$1+k\_{b}=1,42$$

$$1-k\_{b}=0,58$$

$$C\_{d}≝1,23$$

$$C\_{q}≝2,08$$

$$λ\_{b}≝\left(0,785-\frac{b\_{s}⋅10^{-3}}{2⋅d\_{s}}\right)+\frac{h\_{s}⋅10^{-3}}{b\_{s}⋅10^{-3}}$$

$$λ\_{b}=1,07$$

$$λ\_{ду}≝\frac{t\_{Z2}}{12⋅δ`⋅k\_{δ}}$$

$$λ\_{ду}=0,294$$

$$λ\_{Rd}≝0,19⋅\left(\frac{23,6⋅10^{-2}⋅1}{6}\right)$$

$$λ\_{Rd}=0,0075$$

$$x\_{kd`}≝7,9⋅\frac{F\_{aном}⋅10^{-6}}{Φ`\_{δ}⋅\left(1-k\_{b}\right)}⋅\left(\frac{l\_{p}}{N\_{c}}⋅\left(λ\_{b}+λ\_{ду}\right)+λ\_{Rd}\right)$$

$$x\_{kd`}=0,08$$

$$λ\_{Rq}≝0,19⋅\frac{\left(τ⋅C\_{q}\right)}{N\_{c}}$$

120.

$$λ\_{Rq}=0,011$$

$$x\_{kq`}≝7,9⋅\frac{F\_{aном}⋅10^{-6}}{Φ`\_{δ}⋅\left(1+k\_{b}\right)}⋅\left(\frac{l\_{p}}{N\_{c}}⋅\left(λ\_{b}+λ\_{ду}\right)+λ\_{Rd}\right)$$

$$x\_{kq`}=0,033$$

$$r\_{f`}≝\frac{0,44}{10^{8}}⋅\frac{\left(F\_{aном}⋅k\_{ad}^{2}⋅l\_{fcp}\right)}{Φ`\_{δ}⋅f⋅w\_{f}⋅q\_{f}}$$

121.

$$r\_{f`}=0,0029$$

122.

$$C\_{c}≝1$$

$$C\_{кз}≝C\_{c}$$

$$r\_{kd`}≝\frac{2,16}{10^{8}}⋅\frac{F\_{aном}}{f⋅Φ`\_{δ}}⋅\frac{1}{1-k\_{b}}⋅\left(\frac{C\_{c}⋅l\_{c}}{q\_{c}⋅10^{-6}⋅N\_{c}}+\frac{C\_{кз}⋅τ⋅C\_{d}}{q\_{кз}⋅10^{-6}⋅N\_{c}}\right)$$

$$r\_{kd`}=0,0608$$

$$r\_{kq`}≝\frac{2,16}{10^{8}}⋅\frac{F\_{aном}}{f⋅Φ`\_{δ}}⋅\frac{1}{1+k\_{b}}⋅\left(\frac{C\_{c}⋅l\_{c}}{q\_{c}⋅10^{-6}⋅N\_{c}}+\frac{C\_{кз}⋅τ⋅C\_{d}}{q\_{кз}⋅10^{-6}⋅N\_{c}}\right)$$

123.

$$r\_{kq`}=0,025$$

Масса активных материалов

$$b\_{z1`2}≝\frac{π⋅\left(D+h\_{п1}⋅10^{-3}\right)}{Z\_{1}}-b\_{п1}⋅10^{-3}$$

124.

$$b\_{z1`2}=0,0134$$

$$m\_{Z1}≝7800⋅l\_{ст1}⋅k\_{с}⋅h\_{п1}⋅10^{-3}⋅b\_{z1`2}⋅Z\_{1}$$

$$m\_{Z1}=223,5$$

125.

$$m\_{a}≝7800⋅l\_{ст1}⋅k\_{с}⋅π⋅\left(D\_{a}-h\_{a}\right)⋅h\_{a}$$

$$m\_{a}=439$$

$$m\_{м1}≝8900⋅q\_{еф}⋅u\_{п}⋅Z\_{1}⋅\frac{l\_{cp1}}{2}$$

126.

$$m\_{м1}=119,7$$

127.

$$m\_{mf}≝8900⋅q\_{f}⋅l\_{fcp}⋅2⋅p⋅w\_{f}$$

$$m\_{mf}=214$$

$$m\_{мс}≝8900⋅q\_{c}⋅10^{-6}⋅2⋅p⋅N\_{c}⋅l\_{c}$$

128.

$$m\_{мс}=25,4$$

$$m\_{мкз}≝8900⋅q\_{кз}⋅10^{-6}⋅\left(D-2⋅δ-2⋅h\_{s}⋅10^{-3}-2⋅d\_{s}\right)⋅2⋅π$$

129.

$$m\_{мкз}=11,7$$

130.

$$m\_{m}≝7800⋅l`\_{m}⋅k\_{с}⋅2⋅p⋅\left(h\_{m}⋅b\_{m}+0,8⋅h\_{p}⋅b\_{p}\right)$$

$$m\_{m}=652,9$$

131.

$$m\_{j}≝7800⋅l\_{j}⋅π⋅\left(D-2⋅δ-2⋅h\_{mp}-h\_{j}\right)⋅h\_{j}$$

$$m\_{j}=227,839$$

132.

$$m\_{м}≝m\_{м1}+m\_{mf}+m\_{мс}+m\_{мкз}$$

$$m\_{м}=371$$

133.

$$m\_{ст}≝m\_{Z1}+m\_{a}+m\_{м}+m\_{j}$$

$$m\_{ст}=1261,3$$

Потери и КПД

$$P\_{е1}≝m⋅I\_{номф}^{2}⋅r1\_{75}⋅10^{-3}$$

134.

$$P\_{е1}=10$$

$$P\_{f}≝\left(I\_{fном}^{2}⋅r\_{f15}+2⋅ΔU\_{щ}⋅I\_{fном}\right)⋅10^{-3}$$

135.

$$P\_{f}=16,25$$

$$p\_{150}≝1,56$$

136.

$$k\_{да}≝1,3$$

$$k\_{дZ}≝1,7$$

$$P\_{a1}≝k\_{да}⋅p\_{150}⋅\left(B`\_{a}\_{2}\right)^{2}⋅\left(\frac{f}{50}\right)^{1,3}⋅m\_{a}⋅10^{-3}$$

$$P\_{a1}=1,382$$

$$P\_{Z1}≝k\_{дZ}⋅p\_{150}⋅\left(B\_{Z1}\_{2}\right)^{2}⋅\left(\frac{f}{50}\right)^{1,3}⋅m\_{a}⋅10^{-3}$$

137.

$$P\_{Z1}=4,166$$

$$P\_{мех}≝3,68⋅p⋅\left(\frac{V\_{p}}{40}\right)^{3}⋅\sqrt{l\_{1}}$$

138.

$$P\_{мех}=2,221$$

139.

$$B\_{0}≝B\_{δ0}⋅\left(k\_{δ1}-1\right)$$

$$B\_{0}=0,699$$

$$k\_{o}≝4,6$$

$$P\_{пов}≝0,5⋅2⋅p⋅α⋅τ⋅l\_{1}⋅k\_{o}⋅\left(\frac{Z\_{1}⋅n\_{ном}}{10000}\right)^{1,5}⋅\left(B\_{0}⋅t\_{Z1}⋅10^{3}\right)^{2}⋅10^{-3}$$

$$P\_{пов}=6,7$$

$$P\_{1ном}≝\sqrt{3}⋅U\_{ном}⋅I\_{номф}⋅cosφ\_{ном}⋅10^{-3}$$

140.

$$P\_{1ном}=431$$

$$P\_{доб}≝0,005⋅P\_{1ном}$$

$$P\_{доб}=2,153$$

141.

$$ΣP≝P\_{е1}+P\_{f}+P\_{a1}+P\_{Z1}+P\_{мех}+P\_{пов}+P\_{доб}=42,9$$

$$ΣP=42,9$$

$$η≝1-\frac{ΣP}{P\_{1ном}}$$

142.

$$η=0,9$$

Повышение температуры обмотки статора

$$q\_{c}≝\frac{\left(P\_{е1}⋅\frac{l\_{1}}{\frac{l\_{cp1}}{2}}+P\_{доб}+P\_{a1}+P\_{Z1}\right)⋅10^{3}}{π⋅D⋅l\_{1}}$$

143.

$$q\_{c}=12517$$

$$\frac{l\_{1}}{τ}=1,8121$$

144.

$$α`≝80$$

$$υ\_{повс}≝\frac{q\_{c}}{α`⋅\left(1+0,1⋅V\_{p}\right)}$$

$$υ\_{повс}=49,31$$

145.

$$П\_{1}≝a\_{1із}⋅b\_{1із}-2$$

$$П\_{1}=10,312$$

$$γ\_{υ}≝46⋅10^{6}$$

$$q\_{л}≝\frac{A⋅J\_{1}}{γ\_{υ}}⋅\frac{t\_{Z1}}{П\_{1}⋅10^{-2}}$$

$$q\_{л}=1272,3$$

$$Δυ\_{л}≝\frac{q\_{л}}{13,3⋅\left(1+0,07⋅V\_{p}\right)}$$

146.

$$Δυ\_{л}=37,9$$

147.

$$Δυ\_{из}≝11$$

$$Δυ\_{обс}≝\frac{\left(Δυ\_{из}+υ\_{повс}\right)⋅l\_{1}+\left(Δυ\_{из}+Δυ\_{л}\right)⋅l\_{л}}{l\_{1}+l\_{л}}$$

148.

$$Δυ\_{обс}=54,8$$

149.

$$M\_{max`}≝2,0$$

$$E\_{0`}≝1,44$$

$$k\_{pc}≝1,08$$

$$\frac{x`\_{d}-x`\_{q}}{E\_{0`}⋅x`\_{q}}=0,22$$

$$\frac{E\_{0`}}{x`\_{d}⋅cosφ\_{ном}}⋅k\_{pc}=1,9925$$

150.

$$\frac{E\_{0`}}{x`\_{d}}=1,66$$

$$\frac{1}{2}⋅\left(\frac{1}{x`\_{q}}-\frac{1}{x`\_{d}}\right)=0,182$$

$$Θ≝\left[\begin{array}{c}0\\0,523\\1,04\\1,57\\2,09\\2,61\\3,14\end{array}\right]$$

$$M\_{``}≝\vec{1,66⋅sin\left(Θ\right)+0,182⋅sin\left(2⋅Θ\right)}$$

$$M\_{``1}≝\vec{1,66⋅sin\left(Θ\right)}$$

$$M\_{``2}≝\vec{0,182⋅sin\left(2⋅Θ\right)}$$

$$M\_{``}=\left[\begin{array}{c}0\\0,987\\1,591\\1,66\\1,284\\0,682\\0,002\end{array}\right]$$

$$M\_{``1}=\left[\begin{array}{c}0\\0,829\\1,432\\1,66\\1,441\\0,841\\0,003\end{array}\right]$$

$$M\_{``2}=\left[\begin{array}{c}0\\0,158\\0,159\\0\\-0,157\\-0,159\\-0,001\end{array}\right]$$



151.

$$U\_{номф}≝3468$$

$$I\_{номф}≝46$$

$$m≝3$$

$$S\_{ном}≝m⋅U\_{номф}⋅I\_{номф}⋅10^{-3}$$

$$S\_{ном}=479$$

$$I\_{f`ном}≝\left[\begin{array}{c}2,8\\2,2\\1,82\\1,64\end{array}\right]$$

$$Iz`≝\left[\begin{array}{c}1,04\\0,95\\0,9\\0,93\end{array}\right]$$



$$r`\_{f`}≝10⋅r\_{f`}$$

$$r`\_{f`}=0,029$$

$$r\_{kd`}=0,061$$

$$r\_{kq`}=0,025$$

$$s≝\left[\begin{array}{c}1\\0,5\\0,2\\0,1\\0,05\end{array}\right]$$

$$Y\_{fc}≝eval\left(\vec{\frac{1}{\frac{r`\_{f`}}{s}+i⋅x\_{σf`}}}\right)$$

$$Y\_{fc}=\left[\begin{array}{c}0,389-3,655⋅i\\0,753-3,536⋅i\\1,533-2,881⋅i\\1,845-1,733⋅i\\1,423-0,668⋅i\end{array}\right]$$

$$Y\_{kds}≝\vec{\frac{1}{\frac{r\_{kd`}}{s}+i⋅x\_{kd`}}}$$

$$Y\_{kds}=\left[\begin{array}{c}6,017-7,926⋅i\\5,739-3,78⋅i\\3,078-0,811⋅i\\1,618-0,213⋅i\\0,819-0,054⋅i\end{array}\right]$$

$$Y`\_{ds}≝\frac{1}{i⋅x`\_{ad}}+Y\_{kds}+Y\_{fc}$$

$$Y`\_{ds}=\left[\begin{array}{c}6,406-12,855⋅i\\6,492-8,59⋅i\\4,611-4,966⋅i\\3,462-3,22⋅i\\2,242-1,996⋅i\end{array}\right]$$

$$Z`\_{ds}≝\vec{\frac{1}{Y`\_{ds}}}$$

$$Z`\_{ds}=\left[\begin{array}{c}0,031+0,062⋅i\\0,056+0,074⋅i\\0,1+0,108⋅i\\0,155+0,144⋅i\\0,249+0,222⋅i\end{array}\right]$$

$$Z\_{ds}≝i⋅x`\_{σ}+Z`\_{ds}$$

$$Z\_{ds}=\left[\begin{array}{c}0,031+0,145⋅i\\0,056+0,157⋅i\\0,1+0,191⋅i\\0,155+0,226⋅i\\0,249+0,304⋅i\end{array}\right]$$

$$\vec{\frac{1}{Z\_{ds}}}=\left[\begin{array}{c}1,416-6,603⋅i\\2,026-5,663⋅i\\2,164-4,107⋅i\\2,057-3,009⋅i\\1,612-1,97⋅i\end{array}\right]$$

$$Y\_{kqs}≝\vec{\frac{1}{\frac{r\_{kq`}}{s}+i⋅x\_{kq`}}}$$

$$Y\_{kqs}=\left[\begin{array}{c}14,732-19,404⋅i\\14,051-9,254⋅i\\7,535-1,985⋅i\\3,96-0,522⋅i\\2,006-0,132⋅i\end{array}\right]$$

$$Y`≝\frac{1}{i⋅x`\_{aq}}+Y\_{kqs}$$

$$Y`=\left[\begin{array}{c}14,732-21,138⋅i\\14,051-10,987⋅i\\7,535-3,718⋅i\\3,96-2,255⋅i\\2,006-1,865⋅i\end{array}\right]$$

$$Z`\_{qs}≝\vec{\frac{1}{Y`}}$$

$$Z`\_{qs}=\left[\begin{array}{c}0,022+0,032⋅i\\0,044+0,035⋅i\\0,107+0,053⋅i\\0,191+0,109⋅i\\0,267+0,249⋅i\end{array}\right]$$

$$Z\_{qs}≝i⋅x`\_{σ}+Z`\_{qs}$$

$$Z\_{qs}=\left[\begin{array}{c}0,022+0,114⋅i\\0,044+0,117⋅i\\0,107+0,135⋅i\\0,191+0,191⋅i\\0,267+0,331⋅i\end{array}\right]$$

$$\vec{\frac{1}{Z\_{qs}}}=\left[\begin{array}{c}1,637-8,431⋅i\\2,824-7,481⋅i\\3,6-4,558⋅i\\2,617-2,622⋅i\\1,476-1,828⋅i\end{array}\right]$$

$$I\\_`≝\vec{\frac{\left(\frac{1}{Z\_{qs}}+\frac{1}{Z\_{ds}}\right)}{2}}$$

$$I\\_`=\left[\begin{array}{c}1,527-7,517⋅i\\2,425-6,572⋅i\\2,882-4,332⋅i\\2,337-2,815⋅i\\1,544-1,899⋅i\end{array}\right]$$

$$I\\_``≝\vec{\frac{\left(\frac{1}{Z\_{qs}}-\frac{1}{Z\_{ds}}\right)}{2}}$$

$$I\\_``=\left[\begin{array}{c}0,11-0,914⋅i\\0,399-0,909⋅i\\0,718-0,225⋅i\\0,28+0,193⋅i\\-0,068+0,071⋅i\end{array}\right]$$

$$I`≝\left[\begin{array}{c}7,68\\7\\5,2\\3,66\\2,45\end{array}\right]$$

$$I``≝\left[\begin{array}{c}0,92\\0,995\\0,75\\0,34\\0,01\end{array}\right]$$

$$I\_{п}≝\vec{\sqrt{\left(I`\right)^{2}⋅\left(I``\right)^{2}}}$$

$$I\_{п}=\left[\begin{array}{c}7,066\\6,965\\3,9\\1,244\\0,024\end{array}\right]$$

$$I`\_{a}≝\left[\begin{array}{c}1,53\\2,432\\2,887\\2,34\\1,546\end{array}\right]$$

$$M\_{п}≝\vec{\frac{I`\_{a}}{cosφ\_{ном}}}$$

$$M\_{п}=\left[\begin{array}{c}1,7\\2,702\\3,208\\2,6\\1,718\end{array}\right]$$